RADIAN
CORPORATION

ANALYSIS OF DATA
FROM
THE NEW YORK CITY
TAXI I/M PROGRAM

DRAFT REPORT

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1.0 INTRODUCTION

1.1 BACKGROUND

The in-use emission control performance of model year 1980 and newer vehicles is affected by several factors including misfueling, lack of or improper maintenance, and emission control component failure. Although EPA has gathered information on FTP emissions of in-use 1980 and newer vehicles, only limited information is available on the extent that the above factors affect emissions. This study was funded for the purpose of gathering and evaluating Inspection/Maintenance (I/M) emission test data on 1980 and newer taxis operated in New York City. The objectives of this study were to: 1) provide insight into the in-use behavior of 1980 and newer vehicles, especially those with high mileage and 2) learn more about the frequency of different types of malfunctions in 1980 and newer emission control systems and the emissions penalties associated with them.

Since it began operation in October 1977, the New York City taxi I/M program has required all medallion taxis in New York City to pass a short exhaust emissions test three times a year. The program is jointly administered by the NYC Taxi and Limousine Commission and the NYC Department of Environmental Protection (DEP). It uses a decentralized inspection station system of 12 fleet stations and 14 other private inspection stations. At all stations, fleet or private, the inspection is performed by an inspector certified by the Taxi and Limousine Commission. In addition, the DEP operates three emission test vans to spot check taxis on the road. These checks include an idle emission test and a tampering inspection. Taxis that fail the spot check must be retested within 10 days at the DEP's test facility in Brooklyn. 1980 and newer model taxis must comply with idle emission standards of 220 ppm HC and 1.2% CO; no waivers are available.

About 2500 vehicles per month are tested in the New York City taxi I/M program; over half of these are model year 1980 and newer vehicles. Since taxis accumulate mileage at a much faster than average rate, the New York taxi I/M program is a good source of data on high mileage 1980 and newer vehicles. This I/M program has reported failure rates for new technology vehicles that are much higher (20%) than those observed in other I/M programs, suggesting that failure rates may be very sensitive to accumulated mileage.

1.2 SUMMARY OF FINDINGS

Although the I/M and roadside tests do not provide an indication of the emission levels as measured by the Federal Test Procedure (FTP), the results of these tests still provide a picture of the in-use emission control performance of 1980 and newer model vehicles. Following are the major findings of the study:

- 1981 and possibly 1982 vehicles with the 229 cubic inch Chevrolet engines appear to have greater CO and, to a lesser extent, greater HC emissions than 1980 model year vehicles. The closed loop fuel metering system may be responsible for this trend.
- 1981 Dodge vehicles with the 225 cubic inch engines also appear to have greater CO and HC emissions than comparable 1980 models.
- 1981 Ford vehicles have very similar HC and CO emissions to the 1980 models which is expected because of similar fuel metering system designs.
- The failure rate in the I/M test is strongly dependent on odometer reading.
- The HC and CO emission levels of vehicles that pass the I/M test are not strongly affected by odometer reading.
- After repair emission levels of failed vehicles are similar to the emission levels of vehicles that pass the I/M test, regardless of the mileage.
- Although a vehicle could have failed up to four times, most vehicles only failed once or less. 1981 Dodge models show the greatest tendency towards repeat failures.

- A majority of vehicles emitting moderately high amounts of CO also emit moderately high amounts of HC; however, a majority of the moderately high HC emitters do not emit moderately high amounts of CO. The fact that ignition defects affect HC but not CO emissions is most likely responsible for this trend.

- For Chevrolet and Ford vehicles, the percentage of gross CO emitters (greater than 7.0%) does not appear to increase with odometer after approximately 50,000 miles are accumulated.

- The failure rates in the roadside checks are much greater than the failure rate in the I/M test. However, the road side checks do not show significantly greater percentages of gross emitting vehicles (greater than 7.0% CO or 700 ppm HC).

- 1982 Chevrolets with the 229 cubic inch engine have had frequent failures of the evaporative purge values which have resulted in excessive HC and CO emissions and fuel consumption. Oxygen sensors, ECMs, and carburetors have been replaced more frequently than manufacturer's expected intervals.

2.0 ANALYSIS OF DATA FROM I/M AND ROADSIDE TESTS

Taxis operated in New York City accumulated mileage at a rate of approximately 50,000 miles per year. As a result, data collected in the New York Taxi I/M program and during roadside inspections provide a look at the future performance of certain types of new technology vehicles. This section presents the results of analysis of data from the New York City Taxi I/M program.

A majority of the 1980-1982 taxis were Ford, Chevrolet, Checker or Dodge models. In the analysis, the Checker and Chevy vehicles were grouped together because they both used engines built by Chevrolet. According to discussions with fleet operators, most of the Chevrolet or Checker vehicles were equipped with the 229 cubic V6 engine built by the Chevrolet Motor Division of General Motors. The 1980 version utilized an oxidation catalyst for emission control and the fuel control system was open loop, i.e. there was no feedback carburetor. However, the 1980 vehicles did incorporate sealed idle mixture adjustment screws. The 1981 Chevrolets are equipped with a three-way plus oxidation catalyst and a closed loop fuel control system. Most of the Dodge vehicles were equipped with the 225 cubic in-line 6 engine. The 1980 and 1981 models that were certified for 49 states (the federal version) used an open-loop fuel control system. In 1980, an oxidation catalyst was used while 1981 models used a 3-way catalyst and an oxidation catalyst. Most likely the carburetors on the 1981 models were set richer than the 1980 models to enhance NO_x control. Ford taxis were equipped with the 302 cubic inch V8 engine, since this is the only engine available in a full-sized Ford. Like the Dodge vehicles, the 1980 and 1981 models were open-loop; the 1980 models used an oxidation catalyst while the 1981 models used a three-way plus an oxidation catalyst. Most likely the 1981 Ford models also had richer carburetor settings to enhance NO_x control.

The analysis of the I/M and roadside data attempts to address the following questions:

- What is the reliability of closed-loop fuel control systems?
- How do disablement/failure rates vary with mileage?
- Are open-loop systems better for controlling hydrocarbons (HC) and carbon monoxide (CO) emissions from carbureted vehicles?
- Can high mileage vehicles emit HC and CO at low rates?
- What are the emission reductions from repair? Do some vehicles show increases in emissions?
- How accurate are I/M inspections/do they lower in-use disablement rates?
- Are vehicles repaired prior to being inspected?
- How many vehicles are repeat failures?

2.1 Basic Methodology

Radian requested and received from the DEP a tape containing taxi I/M inspection results for the period from January 1, 1982 to May 31, 1983. These data included 7154 inspection records for 1980 model year vehicles, 8904 for 1981, and 2468 for 1982. Very few records were included for 1983 vehicles and as a result, they were excluded from the analysis. Table 2-1 lists the types of data included on the tape. The data initially were analyzed on SAS and a clean data tape was generated.

In order to perform more in-depth data analysis, Radian established additional data sets on the University of Michigan's data base management system, MICRO. MICRO currently contains almost all of the EPA's mobile source emission data; it is a very flexible tool for in-depth analysis. With MICRO, Radian created additional fields that further described the odometer or emission characteristics of the vehicle. These fields include:

TABLE 2-1 LIST OF KEY DATA FIELDS IN THE DATA BASE

New York Taxi I/M Data

Medallion Number
Month of Test
Year of Test
Make of Vehicle
Model Year of Vehicle
Odometer Reading
HC Emissions in ppm
CO Emissions in %
P/F Status
Retest HC
Retest CO
Retest P/F Status
Technician
Inspection Station

Roadside Test Data

Medallion Number
Make of Vehicle
Model Year of Vehicle
HC Emissions in ppm
CO Emissions in %

- Odometer group - group describing mileage of vehicle (0-10,000; 10,000-20,000; etc.)
- HC greater than 300 ppm (yes, no)
- HC greater than 700 ppm (yes, no)
- CO greater than 3.0% (yes, no)
- CO greater than 7.0% (yes, no)
- HC emission reduction (%)
- CO emission reduction (%)

The New York City DEP also provided data sheets containing approximately 800 roadside emission tests on 1980 and newer model year taxis. Data from these data sheets were keypunched and entered into a MICRO data set for analysis. Roadside data were probably more accurate but did not include mileage readings or results of repairs.

In addition to collecting data from the inspection program, Radian conducted personal interviews with maintenance personnel for three of the major taxi fleets: Midland, Metro and 57th Street Metropolian. These interviews were held for the purpose of obtaining information on emission control system failures and are discussed in Section 2.4.

2.1.2 Quality Assurance of Data Base

Several records in the data base were either modified or removed to account for the possibility of inaccuracy:

- CO emission levels and
- Odometer readings.

On the inspection form filled out by the inspector, the CO emissions were recorded to the nearest tenth of a percent. However, the emission analyzers provided a reading to the nearest hundredth of a percent. As a result, a few inspectors recorded the data to the nearest hundredth percent which resulted in the CO emissions being increased by a factor of 10. In order to correct for these occurrences in the data base, a field named error was created to identify vehicles that passed the I/M test but had CO emission levels that would be expected to fail the vehicle. The average error rate was then calculated for each emission test technician and those that had a five percent or greater error rate were removed from the data base. This reduced the total number of records by approximately 20 percent and made a huge difference in the average CO emissions and the CO frequency distribution. The percent of vehicles exceeding the 7 percent CO level was cut in half by these changes and the average emissions were reduced by 25-50 percent.

A more basic approach was used to account for the possibility of inaccurate odometer readings. Since it is very unlikely that a 1980 model taxi would have less than 50,000 miles on it, those that showed less than 50,000 miles on the inspection record were not considered, when trends by odometer were evaluated. Similarly, all 1982 model vehicles with over 50,000 miles also were removed from the data base. As a result of these changes, only the 1981 model year vehicles had a full range of odometer distributions (0-200,000). Figure 2-1 shows a distribution of the vehicle odometer readings.

2.2 ANALYSIS OF I/M DATA

The analysis of the I/M data targeted on:

- Failure rates,
- Emissions distributions,
- Emissions as a function of odometer, and
- Emission reductions.

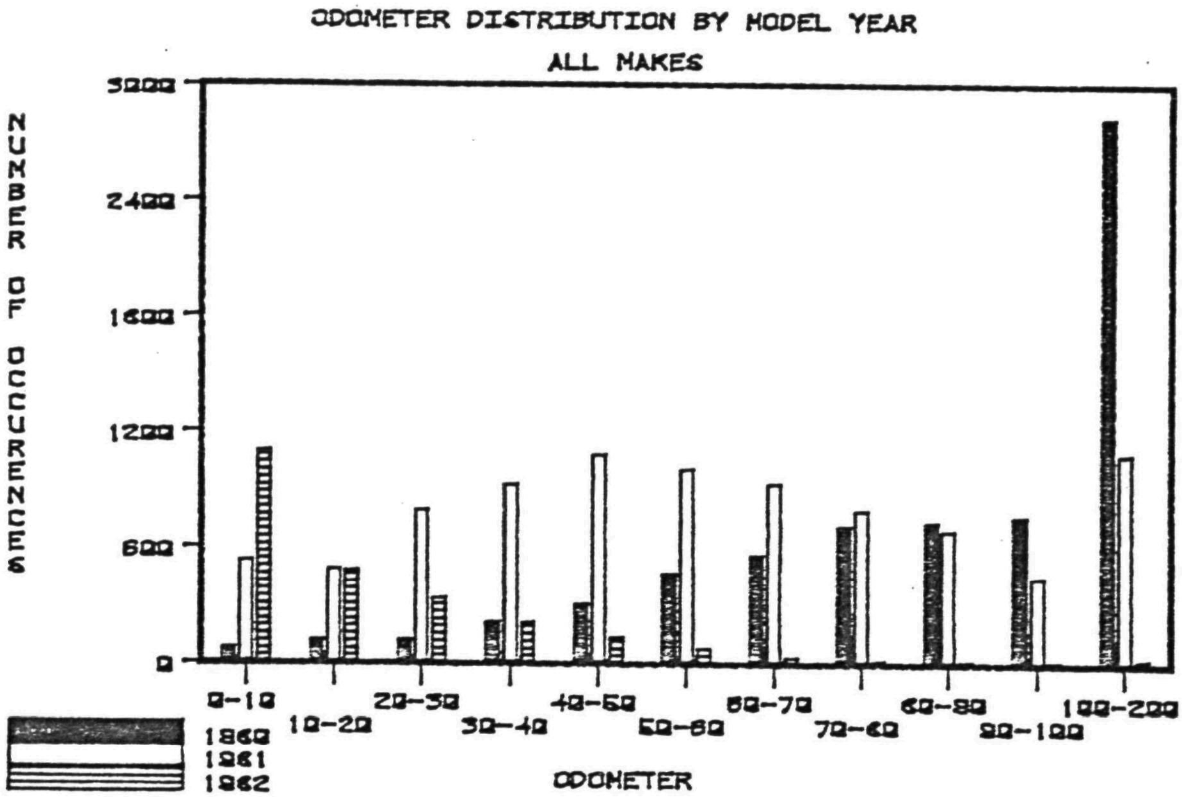


Figure 2-1. Odometer Distributions by Model Year

2.2.1 Analysis of Failure Rates

Radian's analysis of failure rate data was oriented towards determining how successful new emission control technologies have been at reducing HC and CO emissions. By examining these data, Radian wanted to determine how the changes in emission control technologies from 1980 to 1981 affected failure rates and emissions. Failure rates were analyzed as a function of model year, make, and odometer readings.

Failure Rate by Model Year and Make

Table 2-2 summarizes all of the I/M failure rate data analyzed by Radian, broken down by model year and make. In this and subsequent tables, Chevrolets and Checker vehicles are both included as Chevrolets, since they have identical engines. As shown, the 1981 model year vehicles as a group did not have lower failure rates than the 1980 vehicles despite the fact that they had lower mileages. In the case of the Dodge vehicles, the 1981 model showed a failure rate nearly twice that of the 1980 model.

The average HC and CO emissions for passing and failing vehicles of all makes were generally the same, regardless of model year. The same emission cutpoints were used for all vehicles in the I/M tests so this generalization appears reasonable. However, there were some notable exceptions. In the case of Chevrolets, the CO emissions from failed vehicles greatly increased from 1980 to 1981. This trend indicates that I/M failures in 1981 Chevrolets tend to be the result of rich engine failures, while 1980 models failed largely for HC only problems, such as ignition defects. Also, 1982 vehicles that passed the test had significantly lower emission levels.

For all makes, the filed vehicles had higher average odometer readings than the passing vehicles. This indicates that, as expected, mileage affects the I/M failure rate.

TABLE 2-2 FAILURE RATES

Model Year	Make	Avg. Odometer Pass	Avg. Odometer Fail	% Failure	Avg. HC (ppm) Pass	Avg. HC (ppm) Fail	Avg. CO (%) Pass	Avg. CO (%) Fail	Count
1980	All	92K	104K	14%	77.3	497	0.31	2.44	7154
	Chevy*	96K	109K	13%	86.7	574	0.29	1.09	3454
	Dodge	87K	97K	14%	63.6	331	0.34	4.04	565
	Ford	91K	100K	16%	74.2	452	0.33	3.48	2896
1981	All	56K	77K	16%	79.4	441	0.27	3.11	8904
	Chevy*	56K	73K	13%	82.1	509	0.27	2.77	4860
	Dodge	60K	86K	27%	78.7	383	0.26	3.16	2444
	Ford	48K	58K	11%	76.1	404	0.28	4.72	1488
1982	All	18K	30K	4.5%	60.6	409	0.14	2.30	2460
	Chevy*	18K	28K	4%	61.5	470	0.13	2.25	1773
	Dodge	21K	33K	7%	67.1	275	0.18	1.90	393
	Ford	12K	45K	4%	47.0	307	0.12	3.77	283

* Includes Checker

Failure Rate by Odometer Reading

Figure 2-2 shows failure rates for all 1980, 1981, and 1982 model year vehicles as a function of vehicle odometer readings. As shown, failure rates increase consistently with increases in odometer readings. Figure 2-3 shows a more in-depth examination of this trend; in this case, failure rate is shown as a function of odometer reading for each of the model years 1980, 1981, and 1982. This analysis reveals that 1981 model year vehicles have significantly higher failure rates than 1980 model year vehicles with similar odometer readings. Odometer readings shown on these figures were the midpoint of the interval examined. For example, 5,000 relates to the 0-10,000 mile interval.

When the failure rate versus odometer reading is broken down by vehicle make, other patterns become evident. Figure 2-4 shows failure rates versus odometer readings for 1980-1982 model year Chevrolet/Checker vehicles. Here the failure rate for the 1981 vehicles is much higher than that for the 1980 vehicles for all odometer readings from 50,000 to 150,000. This indicates that the closed loop fuel control system used in the 1981 vehicles appears to be less reliable at controlling emissions than the open loop system with sealed idle adjustment screws used on the 1980 Chevrolets.

In Figure 2-5, the Dodge vehicle failure rate is plotted as a function of odometer reading. Here again, the 1981 vehicles have a consistently much higher failure rate across all odometer readings. The greater failure rate of the 1981 vehicles may be due to richer or more sensitive carburetor adjustments required to meet the 1981 NO_x standard. However, the 1981 vehicles had sealed idle adjustment screws which should have caused some drop in their failure rate. These problems may not be a serious vehicle emission concern since more than 90 percent of Chrysler vehicles have four cylinder engines with significantly different engine designs than the 225-6.

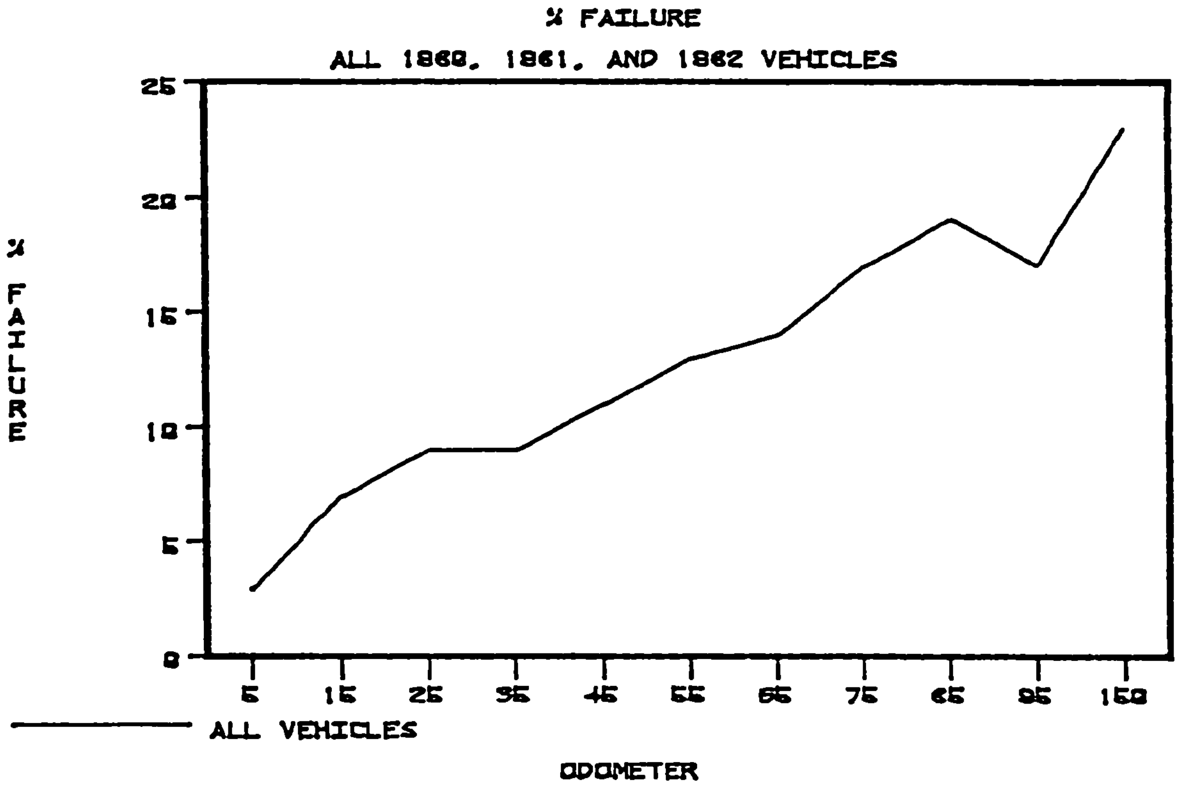


Figure 2-2. Failure Rates vs. Odometer Readings for All Vehicle Makes and All Model Years (1980-1982)

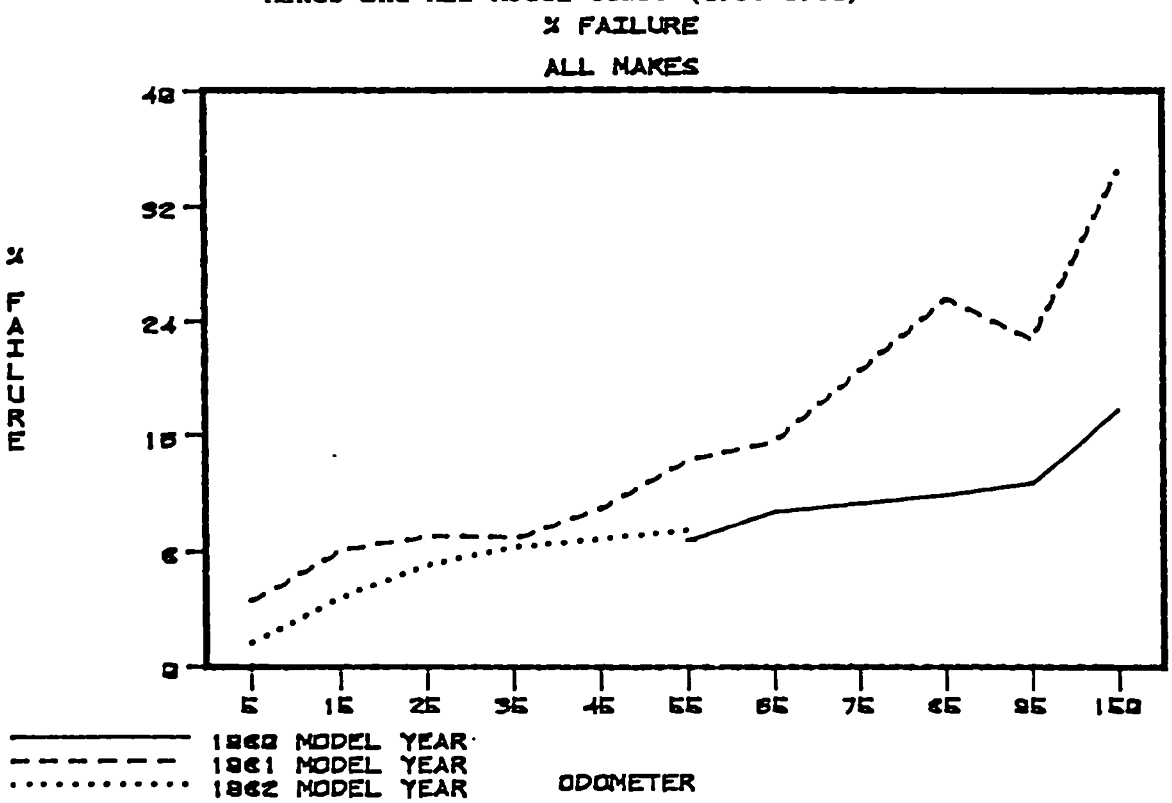


Figure 2-3. Failure Rates vs. Odometer Readings for All Vehicle Makes for Model Years 1980, 1981, and 1982

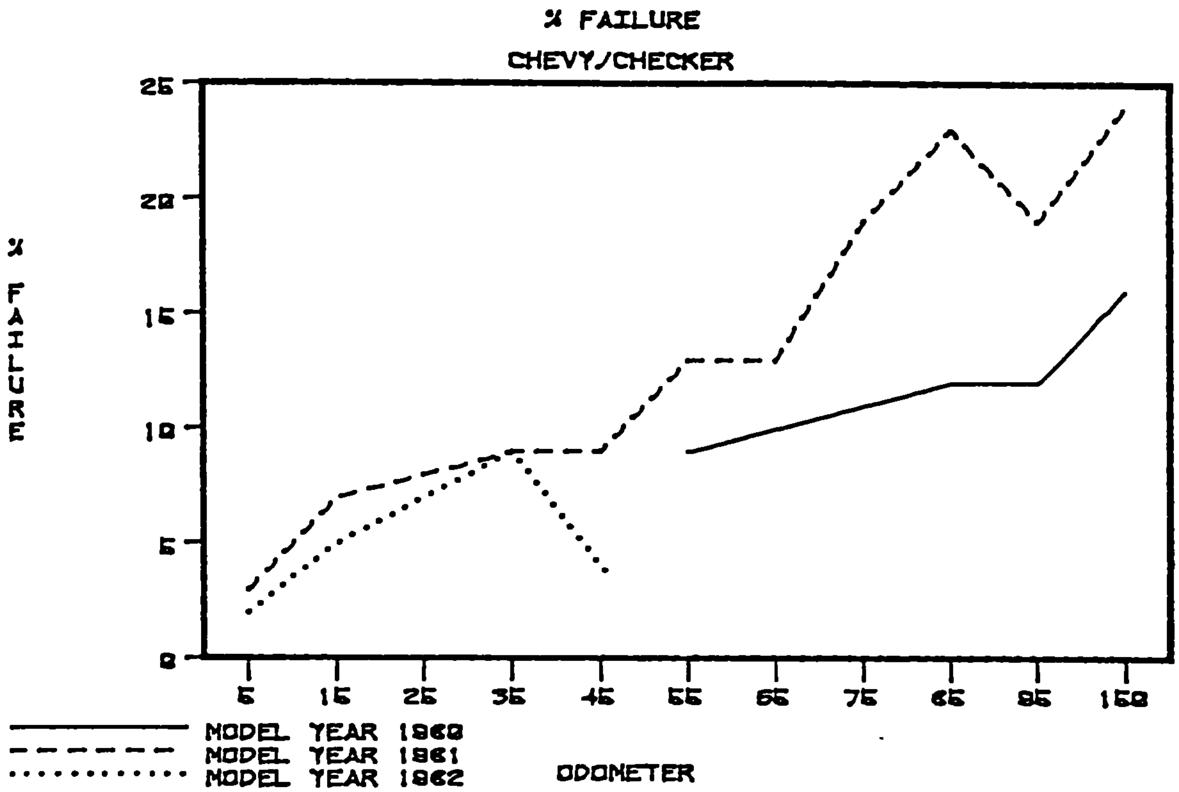


Figure 2-4. Failure Rates for Model Year 1980, 1981, and 1982 Chevrolet/Checker Vehicles vs. Odometer Readings

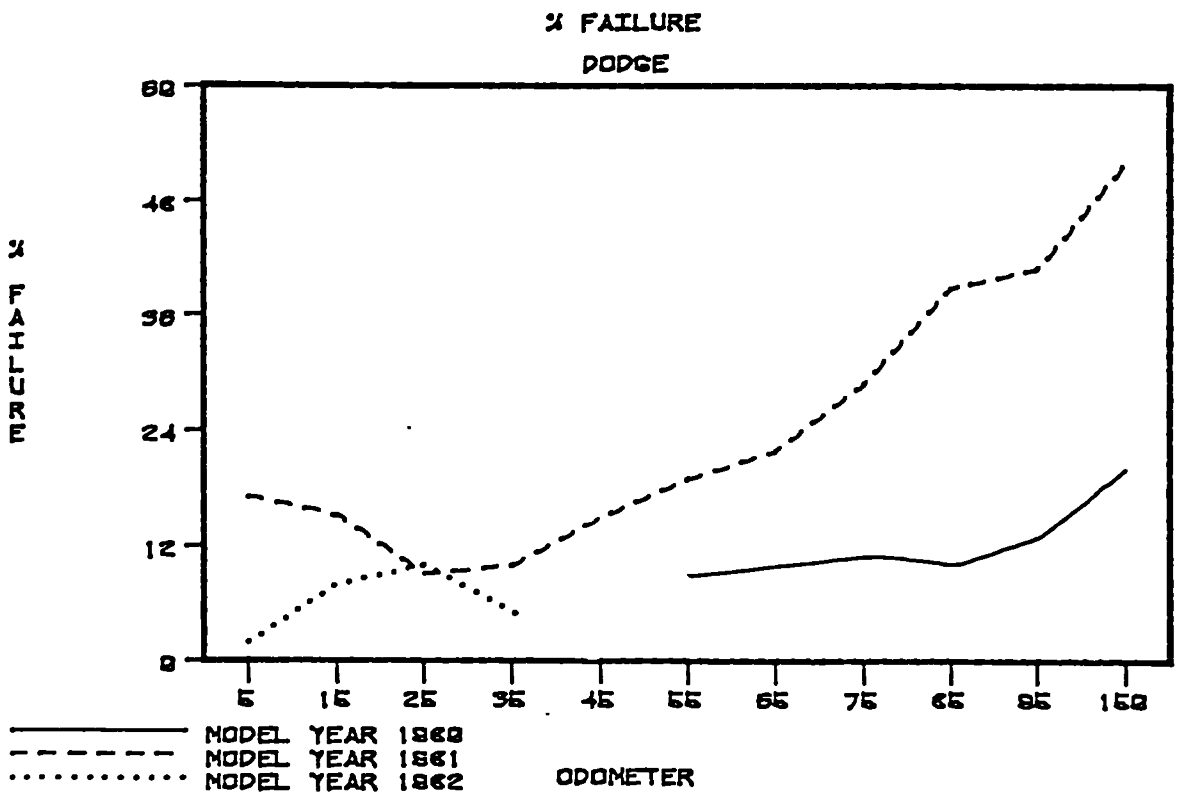


Figure 2-5. Failure Rates for Model Year 1980, 1981, and 1982 Dodge Vehicles vs. Odometer Readings

The failure rate of Ford vehicles versus odometer reading for the 1980-1982 model years is plotted in Figure 2-6. In this case, the 1981 failure rate is very similar to the 1980 rate. Most 1981 Fords have open loop fuel control systems similar to the systems found in the 1980 models, so this agreement in failure rates is not surprising.

Since the data base covered approximately 16 months, each vehicle was inspected approximately 4 times and therefore could have failed 4 times. Table 2-3 shows the percent of vehicles that failed the I/M test more than once. As shown, most of the vehicles in the data base had not failed the I/M test previously. When the vehicles that failed more than once are examined, the 1981 Dodge models appear to be most prone to repeat failures. This makes sense since the Dodge models are open loop and more prone towards being readjusted after repair to compensate for a driveability problem. Also, the 1981 Dodges have the highest failure rate which increases the chance that they will fail more than once.

2.2.2 Analysis of Emissions Distributions

Additional insight into the cause of I/M failures can be obtained by analyzing the distribution of emission levels. In this analysis, vehicles were grouped into the following categories:

- HC greater than 300 ppm,
- HC greater than 700 ppm,
- CO greater than 3.0%, and
- CO greater than 7.0%.

Emission distribution trends were then analyzed as a function of odometer. Table 2-4 shows the percent of vehicles in the above categories for each combination of make and model year. As shown, 1981 Dodge models have the highest percentage of vehicles with excessive HC or CO emissions. The 1981

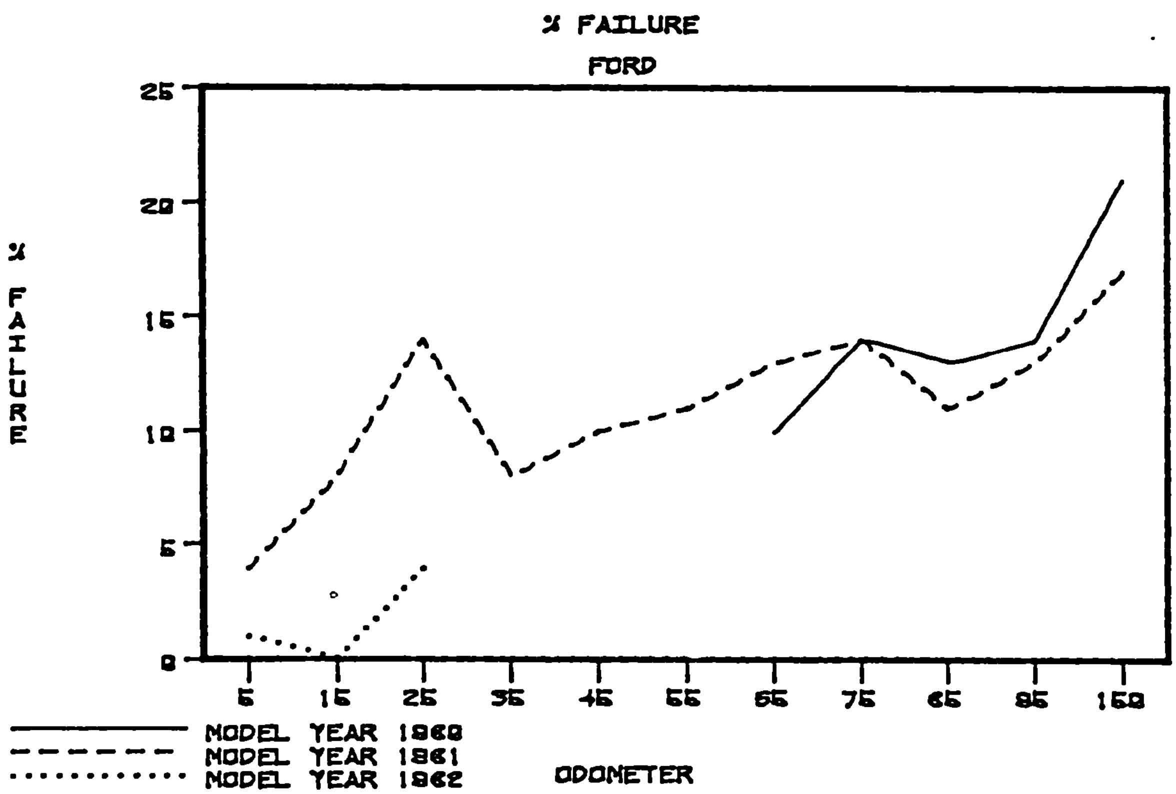


Figure 2-6. Failure Rates for Model Year 1980, 1981, and 1982 Ford Vehicles vs. Odometer Reading

TABLE 2-3

VEHICLES FAILING I/M TEST MORE THAN ONCE

Model Yr.	Make	Total # of Vehicles	Vehicles Failing Once #	%	Vehicles Failing Twice #	%	Vehicles/3 Times #	%	Vehicles/4 Times #	%
1980	All	7130	654	9.2%	276	3.9%	54	0.8%	16	0.2%
	Chevy	3448	300	8.7%	126	3.7%	21	0.6%	--	0
	Dodge	565	60	10.6%	18	3.2%	3	0.5%	--	0
	Ford	2896	294	10.2%	132	4.6%	30	1.0%	16	0.6%
1981	All	8879	923	10.4%	406	4.6%	114	1.3%	20	0.2%
	Chevy	4856	428	8.8%	180	3.7%	36	0.7%	12	0.2%
	Dodge	2444	376	15.4%	196	8.0%	69	2.8%	8	0.3%
	Ford	1488	119	8.0%	30	2.0%	9	0.6%	--	0%
1982	All	2454	106	4.3%	6	0.2%	--	0%	--	0%
	Chevy	1772	75	4.2%	--	0%	--	0%	--	0%
	Dodge	393	23	5.8%	4	1.0%	--	0%	--	0%
	Ford	283	8	2.8%	2	0.7%	--	0%	--	0%

TABLE 2-4

PERCENT OF VEHICLES EXCEEDING IDLE EMISSION LEVELS

Model Year	Make	% Exceeding Idle HC (ppm) > 300	% Exceeding Idle HC (ppm) > 700	Emission Levels CO (%) > 3.0	Emission Levels CO (%) > 7.0
1980	All	9.2%	2.9%	4.0%	1.11%
Chevy *		10.0%	3.9%	1.5%	0.3%
Dodge		6.4%	1.1%	4.9%	1.9%
Ford		9.5%	2.4%	7.1%	2.0%
1981	All	9.3%	2.5%	7.3%	1.8%
Chevy *		8.7%	2.8%	5.1%	1.7%
Dodge		12.6%	2.8%	11.5%	2.1%
Ford		6.4%	1.1%	7.0%	2.0%
1982	All	2.6%	0.7%	1.0%	0.30%
Chevy *		2.8%	0.8%	1.0%	0.3%
Dodge		2.3%	0.5%	1.5%	0%
Ford		1.8%	0.0%	.6%	.6%

* Including Checker

Chevrolet vehicle population has significantly greater percentages of high CO emitters than their 1980 counterparts, while Ford vehicles show little change from 1980 to 1981. However, despite the increase, the 1981 Chevrolets do not appear to be higher CO or HC emitters than the Ford models.

Table 2-5 presents a cross-tabulation of the high emitting CO vehicles with the high emitting HC vehicles. As shown, a majority of the moderately high hydrocarbon emitting vehicles--those greater than 300 ppm--did not have high CO emissions. On the other hand, the majority of the moderately high CO emitting vehicles did have high HC emissions. This makes sense since the factors that cause high CO emissions will also cause high HC emissions, while the reverse is not always true. When the vehicles with gross emissions, i.e., those over 7% CO or 700 ppm HC are examined, it appears that both the gross HC and the gross CO emitters occur independently of each other (see Table 2-6).

Figure 2-7 shows the percentage of all vehicles with moderately high HC emissions versus odometer readings for model years 1980-1982. In Figure 2-8, the same relationship is again shown, but for vehicles with gross HC emissions. Figures 2-9 and 2-10 show the percentage of all vehicles with more than 3.0 percent (moderately high) and more than 7.0 percent (gross) CO emissions, respectively. Again this percentage is plotted versus odometer readings for model years 1980-1982.

Although some inconsistencies are present, the overall trend is towards a greater percentage of high emitters at higher odometer readings. As shown in Figure 2-7, a greater percentage of 1981 vehicles than 1980 vehicles exceeded 300 ppm HC emissions. Examination of the percentage of gross HC emitting vehicles by model year shows that a somewhat greater percentage of 1981 vehicles than 1980 vehicles have emissions that exceed 700 ppm. However, as shown, the difference between the percent of 1981 and 1980 vehicles exceeding 700 ppm is not as large as the difference between the percent of 1981 and 1980 vehicles with HC greater than 300 ppm. It is

TABLE 2-5 CROSS TABULATION OF MODERATELY HIGH EMITTING VEHICLES

Vehicle Emission Category	Count	Percent
CO <3.0%, HC <300 ppm	12766	90%
CO <3.0%, HC >300 ppm	605	4.3%
CO >3.0%, HC <300 ppm	321	2.3%
CO >3.0%, HC >300 ppm	438	3.1%

TABLE 2-6 CROSS TABULATION OF GROSS EMITTING VEHICLES

Vehicle Emission Category	Count	Percent
CO <7.0%, HC <700 ppm	13665	97%
CO <7.0%, HC >700 ppm	269	2.0%
CO >7.0%, HC <700 ppm	140	1.0%
CO >7.0%, HC >700 ppm	56	0.4%

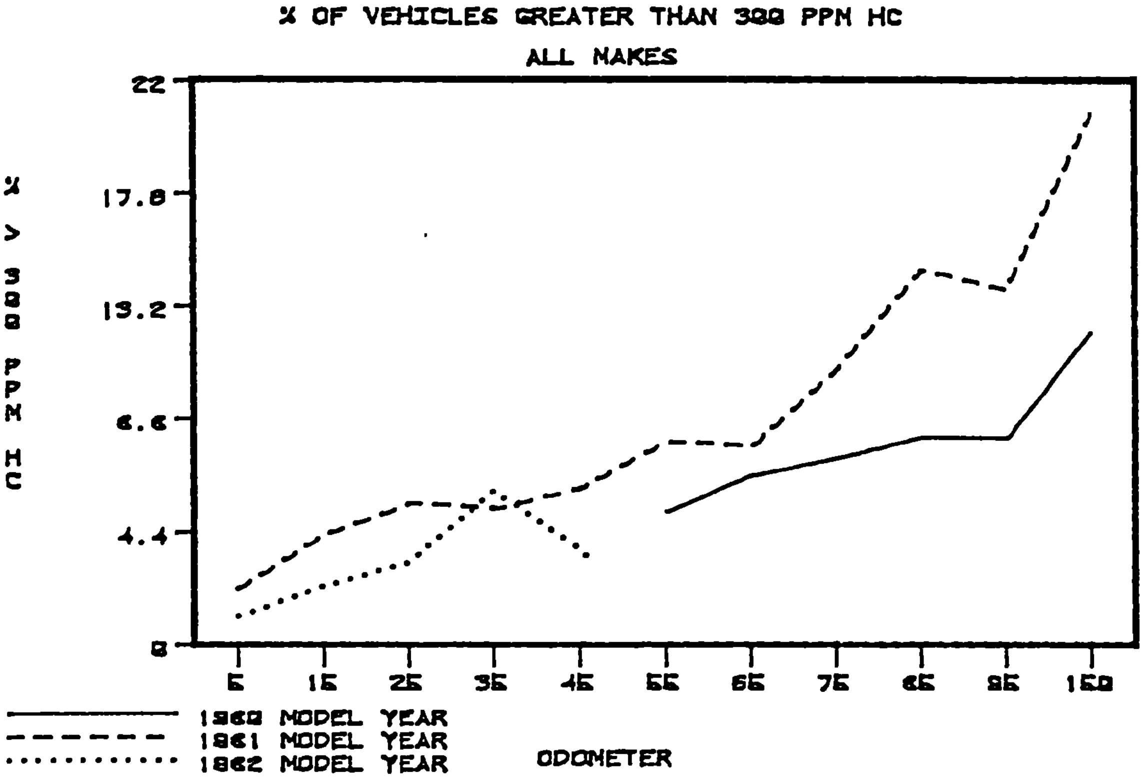


Figure 2-7. Percentage of Vehicles (All Makes) With Emissions Greater Than 300 ppm HC Emissions vs. Odometer Reading

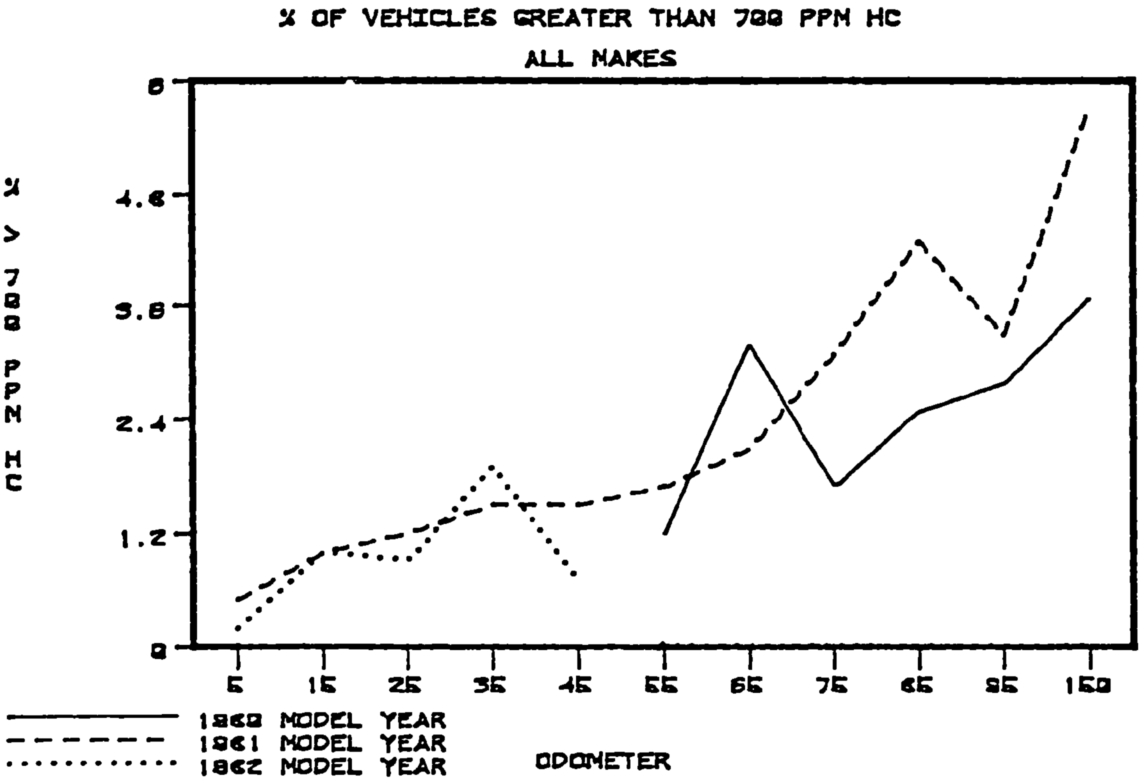


Figure 2-8. Percentage of Vehicles (All Makes) With Emissions Greater Than 700 ppm HC Emissions vs. Odometer Reading

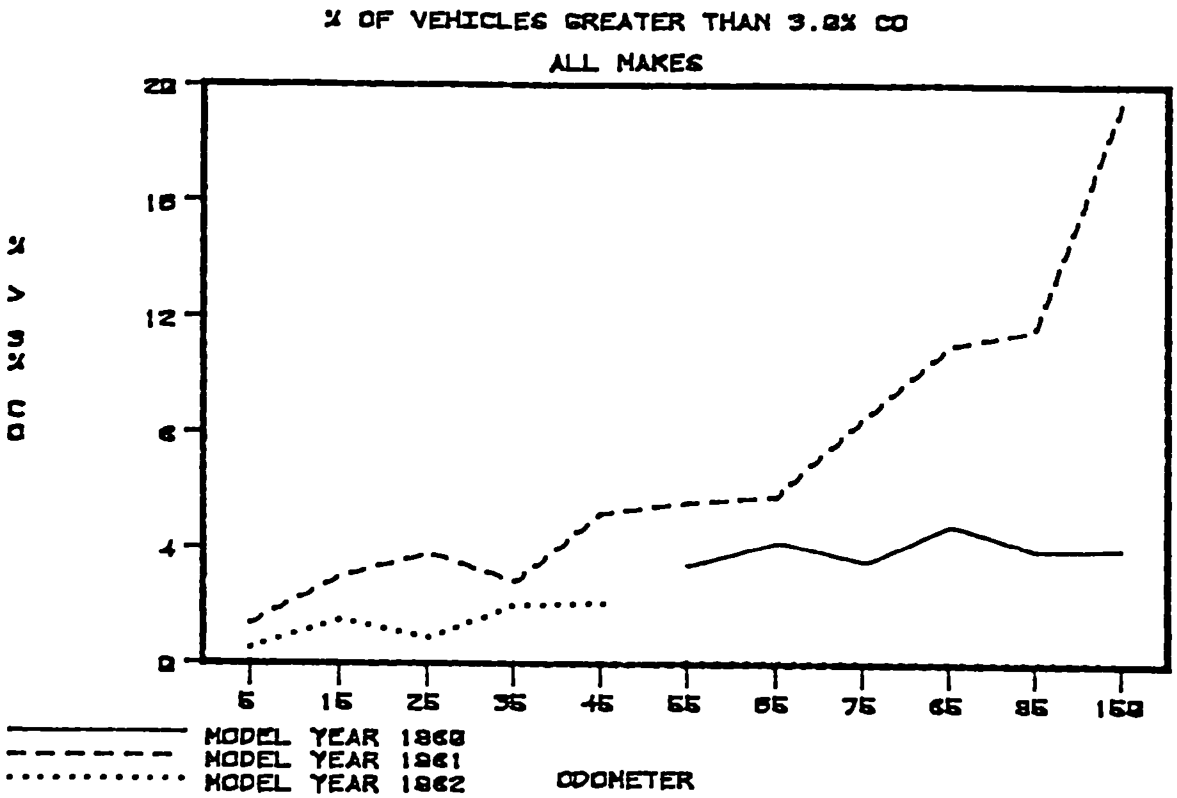


Figure 2-9. Percentage of Vehicles (All Makes) With Greater Than 3.0% CO Emissions vs. Odometer Readings

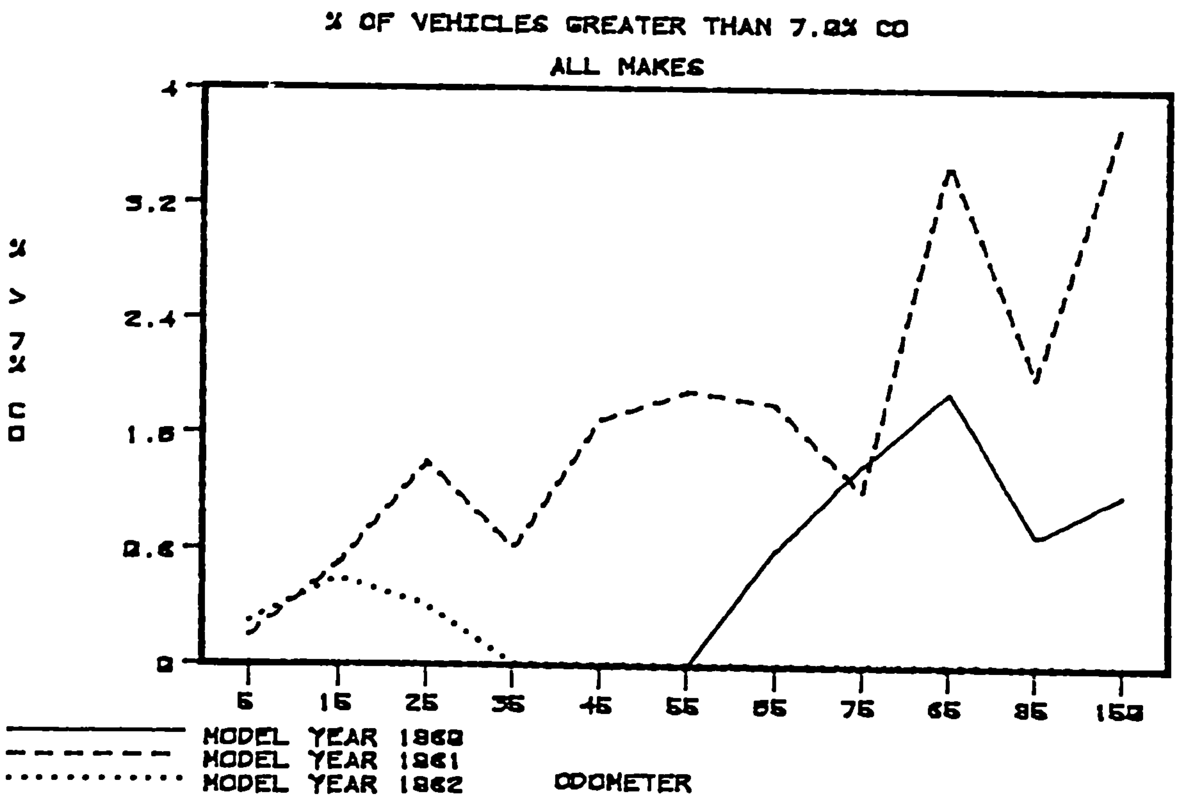


Figure 2-10. Percentage of Vehicles (All Makes) With Greater Than 7.0% CO Emissions vs. Odometer Reading

possible that vehicles exceeding 300 ppm but not 700 ppm HC have fuel-related problems, while those that exceed 700 ppm HC have ignition-related problems. The major change from 1980 to 1981 was in the fuel metering system.

As shown in Figure 2-9, a noticeably higher number of 1981 vehicles exceed the 3% CO level than do 1980 vehicles and the number appears to be very sensitive to odometer reading. Again, this is evidence of the fuel control problems that appear to exist in 1981 vehicles. The percentage of vehicles with more than 7 percent CO (Figure 2-10) is also higher for 1981 than for 1980 model year vehicles, although the absolute percentage is still low, 3 percent.

Trends by Vehicle Make

Chevrolet/Checker

CO emissions were studied for indication of control and full rich engine failures expected in some of the Chevrolet computer controlled engines. As can be seen in Figures 2-11 through 2-14, the 1981 model year Chevrolet/Checker vehicles have a greater tendency towards high HC and CO emissions, indicating the presence of fuel-related problems in this model year vehicle. For HC, the percent of vehicles exceeding 300 ppm is very similar for model years 1980 and 1981 until the odometer reading exceeds 65,000. Then the percent of moderately emitting 1981 vehicles sharply increases, while the 1980 rate only slightly increases. The 1981 vehicles do not appear to have a greater percent of gross HC emitters (greater than 700 ppm) which could be expected.

In the case of CO, a much greater percentage of model year 1981 vehicles exceed 3.0% and 7.0% than do 1980 vehicles. Also, as shown in Figure 2-12, the percentage of gross CO emitters (greater than 7.0%) does not appear to be strongly influenced by mileage after an initial increase during the first 50,000 miles except for an outlier point at 85,000 miles. Possibly a disablement of one or more emission related control sensors causes

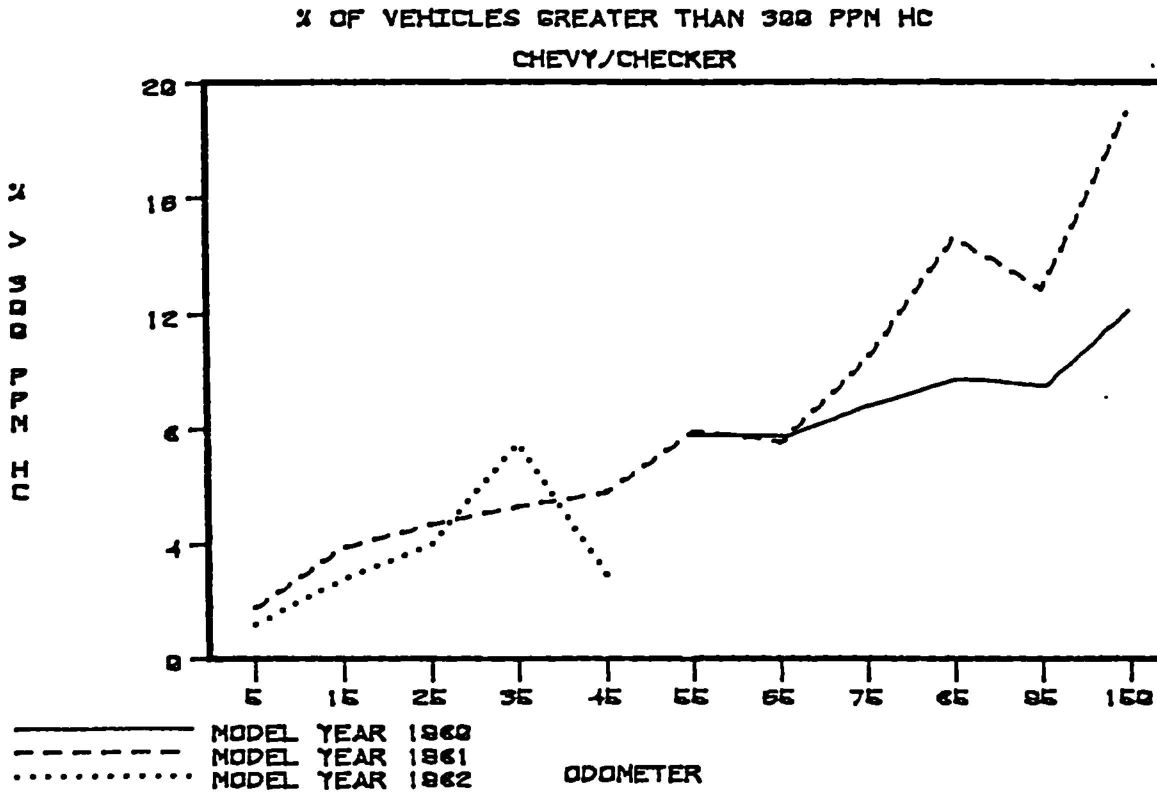


Figure 2-11. Percentage of Chevrolet/Checker Vehicles With Greater Than 300 ppm HC Emissions vs. Odometer Reading

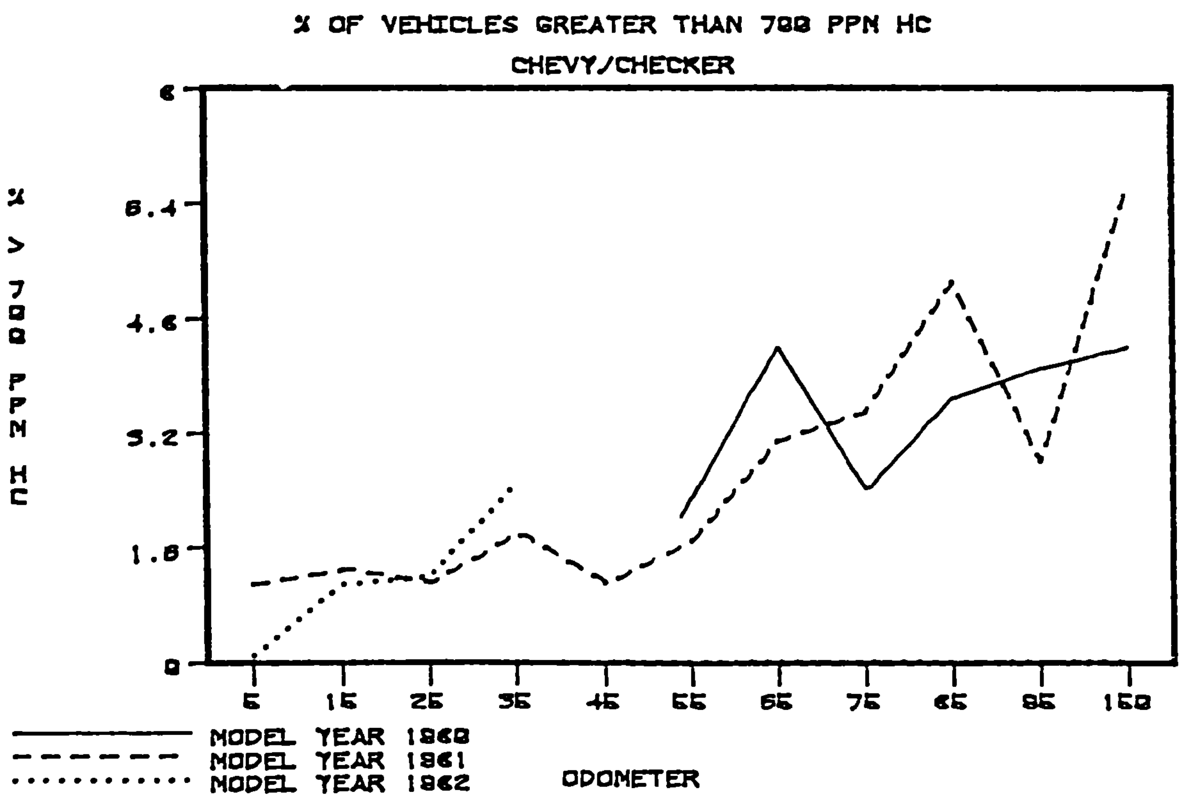


Figure 2-12. Percentage of Chevrolet/Checker Vehicles With Greater Than 700 ppm HC Emissions vs. Odometer Reading

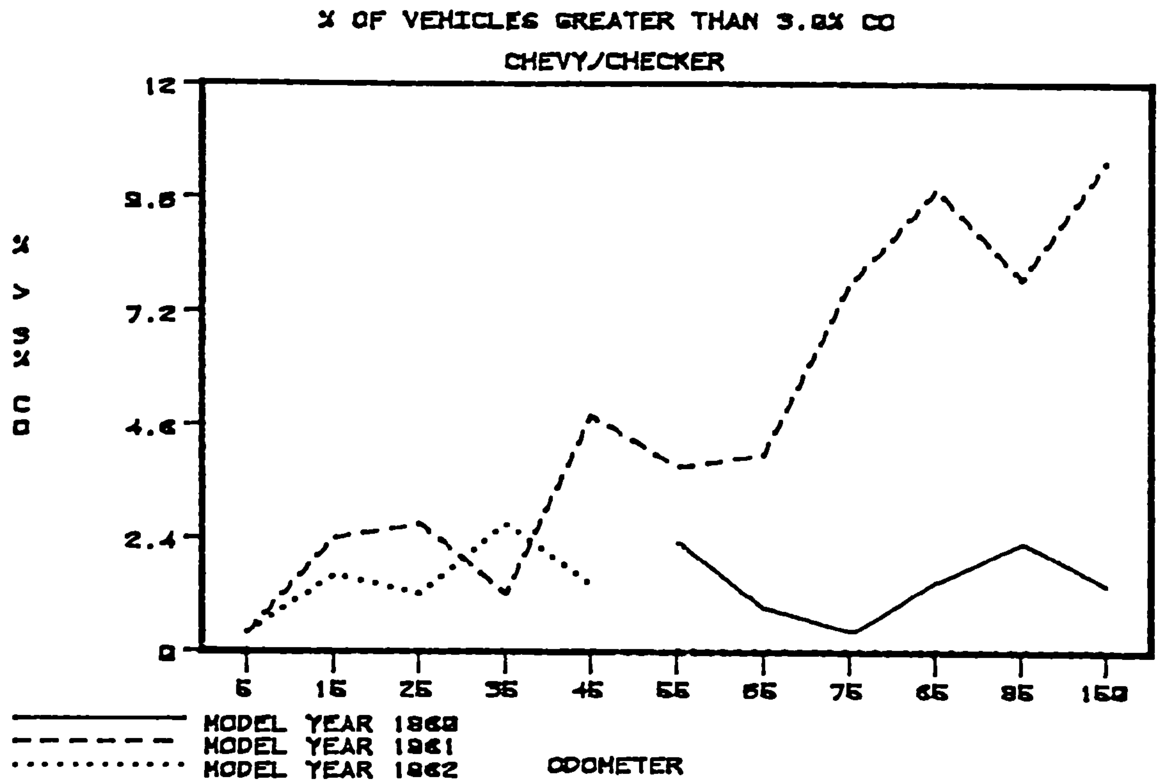


Figure 2-13. Percentage of Chevrolet/Checker Vehicles With Greater Than 3.0% CO Emissions vs. Odometer Reading

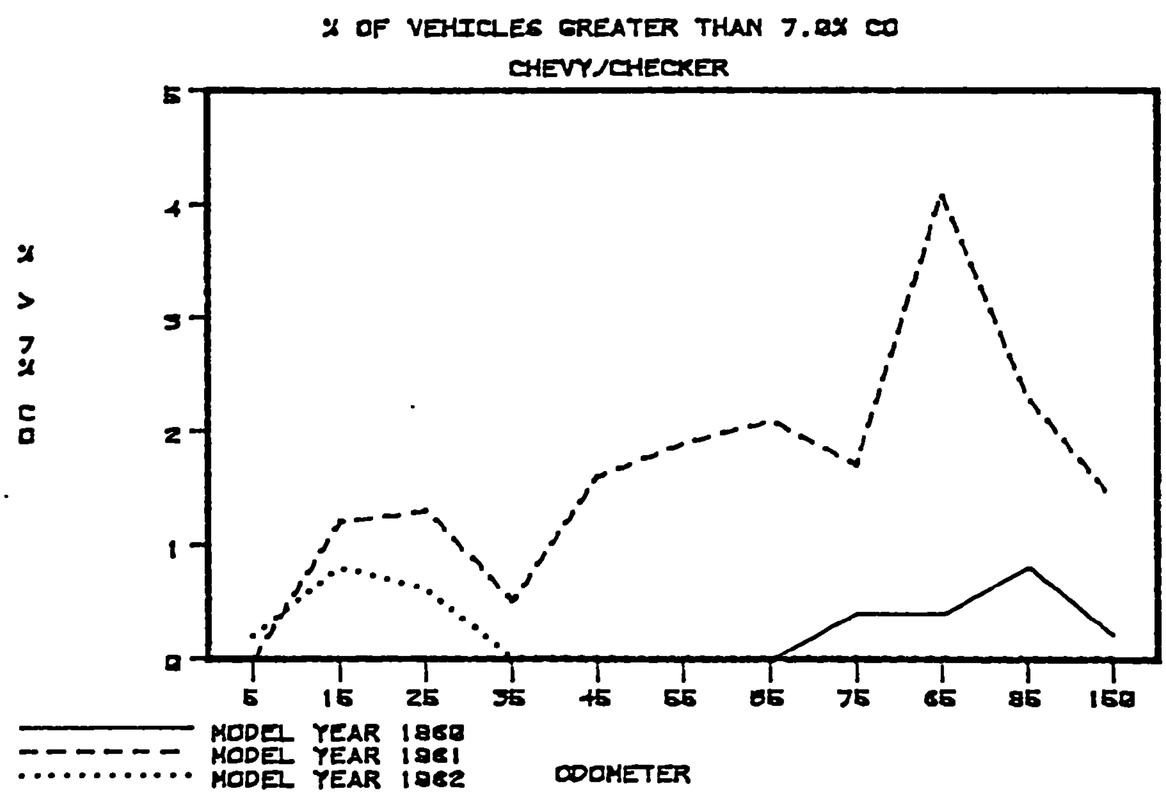


Figure 2-14. Percentage of Chevrolet/Checker Vehicles With Greater Than 7.0% CO Emissions vs. Odometer Reading

the engine to run in the "control rich" mode resulting in moderately, rather than grossly elevated CO levels. Also, driveability may be impaired or the owner/operator may have some other indication of a problem when a vehicle exceeds 7.0% CO.

Fords

Figures 2-15 through 2-18 show the distribution of Ford vehicles with excess HC and CO emissions. Examination of data on moderately high and grossly emitting Ford vehicles shows that the 1981 vehicles do not have higher HC emissions than the 1980 models. Also, it shows that 1981 vehicles have roughly the same percentage of moderately high and gross CO emitters as the 1980 model year. Since 1981 Fords have similar fuel control systems to the 1980 models, i.e., open loop, these results are not surprising.

There were an inadequate number of 1980 Dodge vehicles to perform a valid comparison of CO and HC emissions distribution between the two model years.

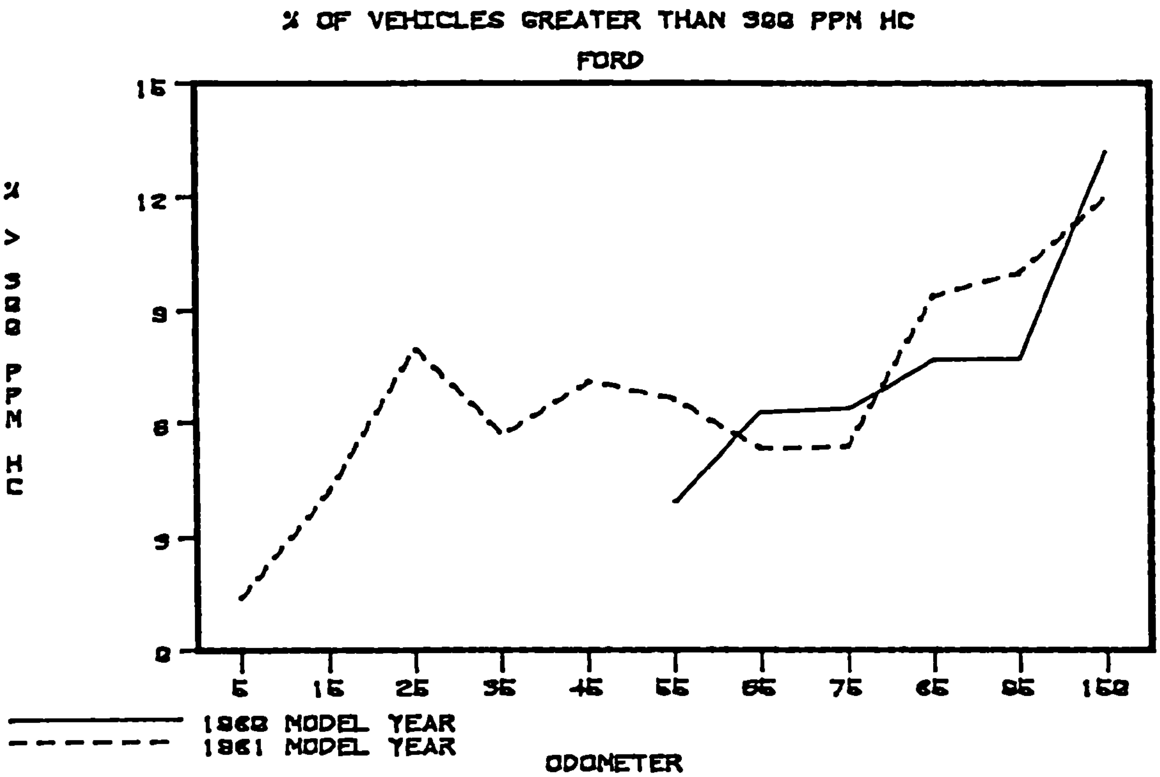


Figure 2-15. Percentage of Ford Vehicles With Greater Than 300 ppm HC Emissions vs. Odometer Reading

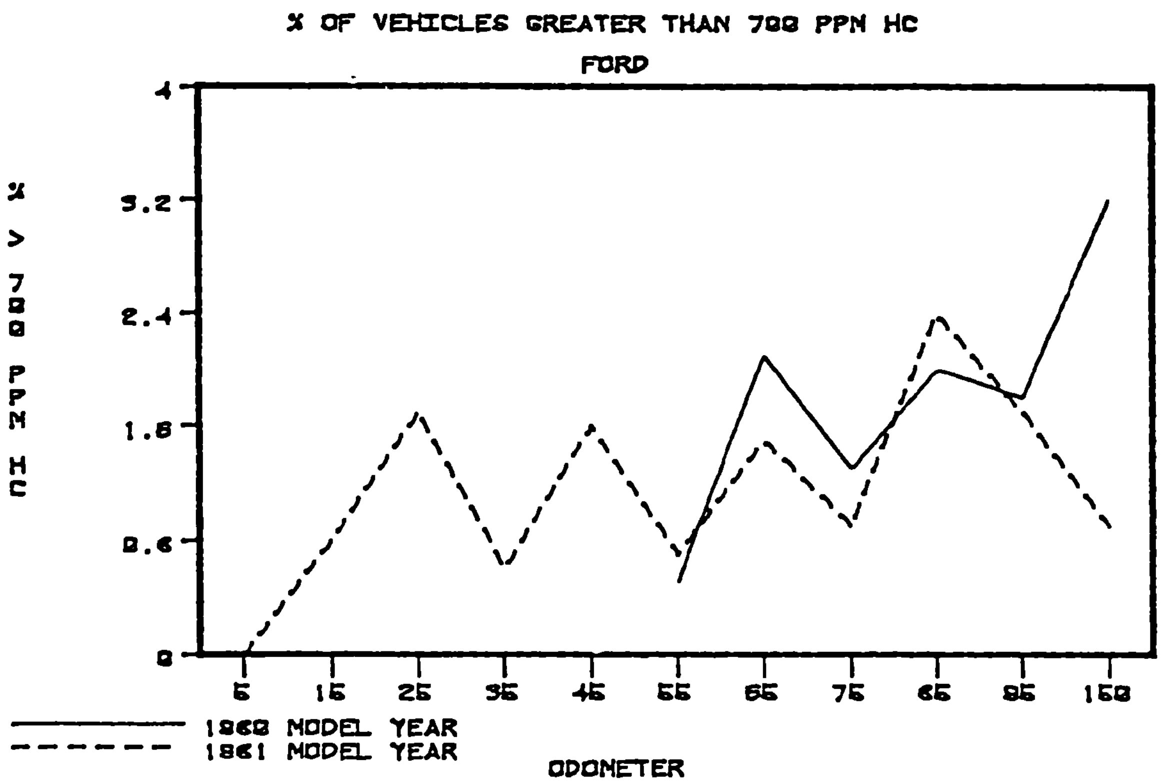


Figure 2-16. Percentage of Ford Vehicles With Greater Than 700 ppm HC Emissions vs. Odometer Reading

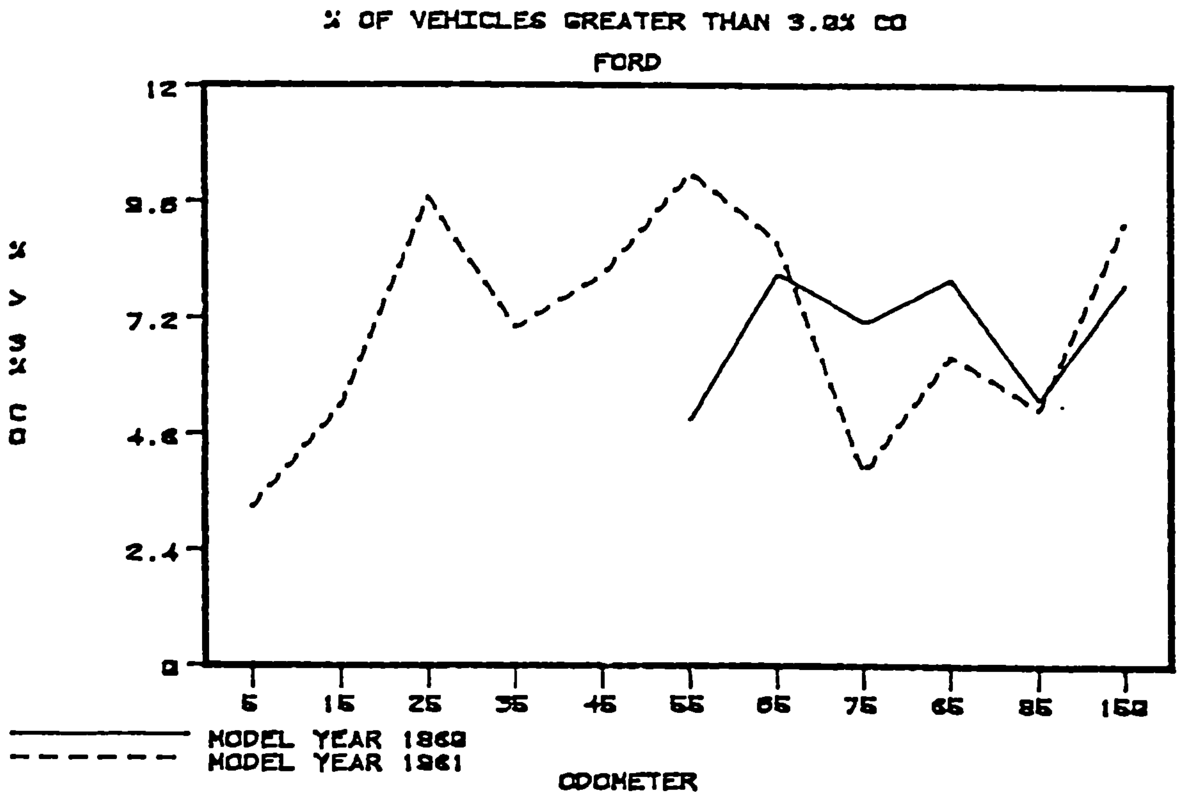


Figure 2-17. Percentage of Ford Vehicles With Greater Than 3.0% CO Emissions vs. Odometer Reading

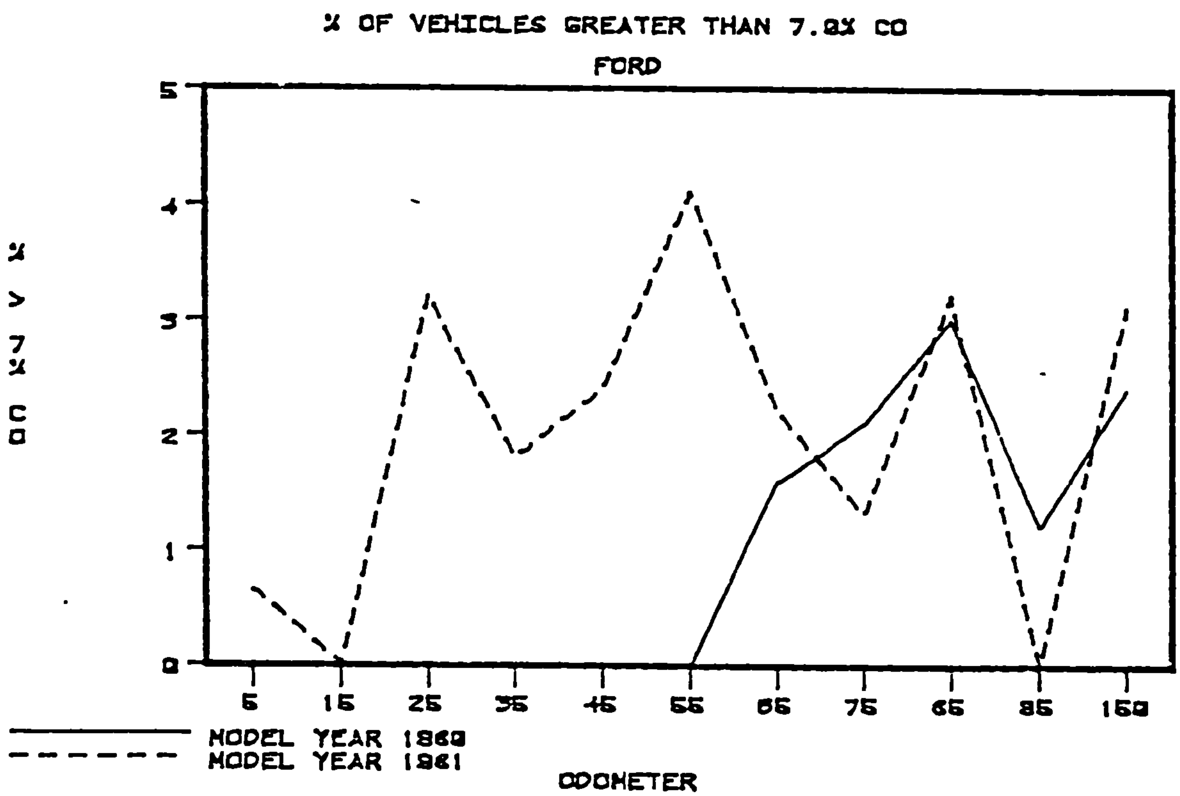


Figure 2-18. Percentage of Ford Vehicles With Greater Than 7.0% CO Emissions vs. Odometer Reading

2.2.3 Emissions As A Function of Odometer

Scatter plots of the HC and CO emission for the 1981 model year as a function of odometer are shown on Figures 2-19 and 2-20. As shown, emission levels do not consistently increase as a function of odometer reading. At the higher odometer reading, there appears to be a few more vehicles in the high emitting category, but the bulk of the vehicles are still in the low emitting category. Correlation coefficients were determined for HC and CO emissions as a function of odometer and the coefficient was not significantly different from zero.

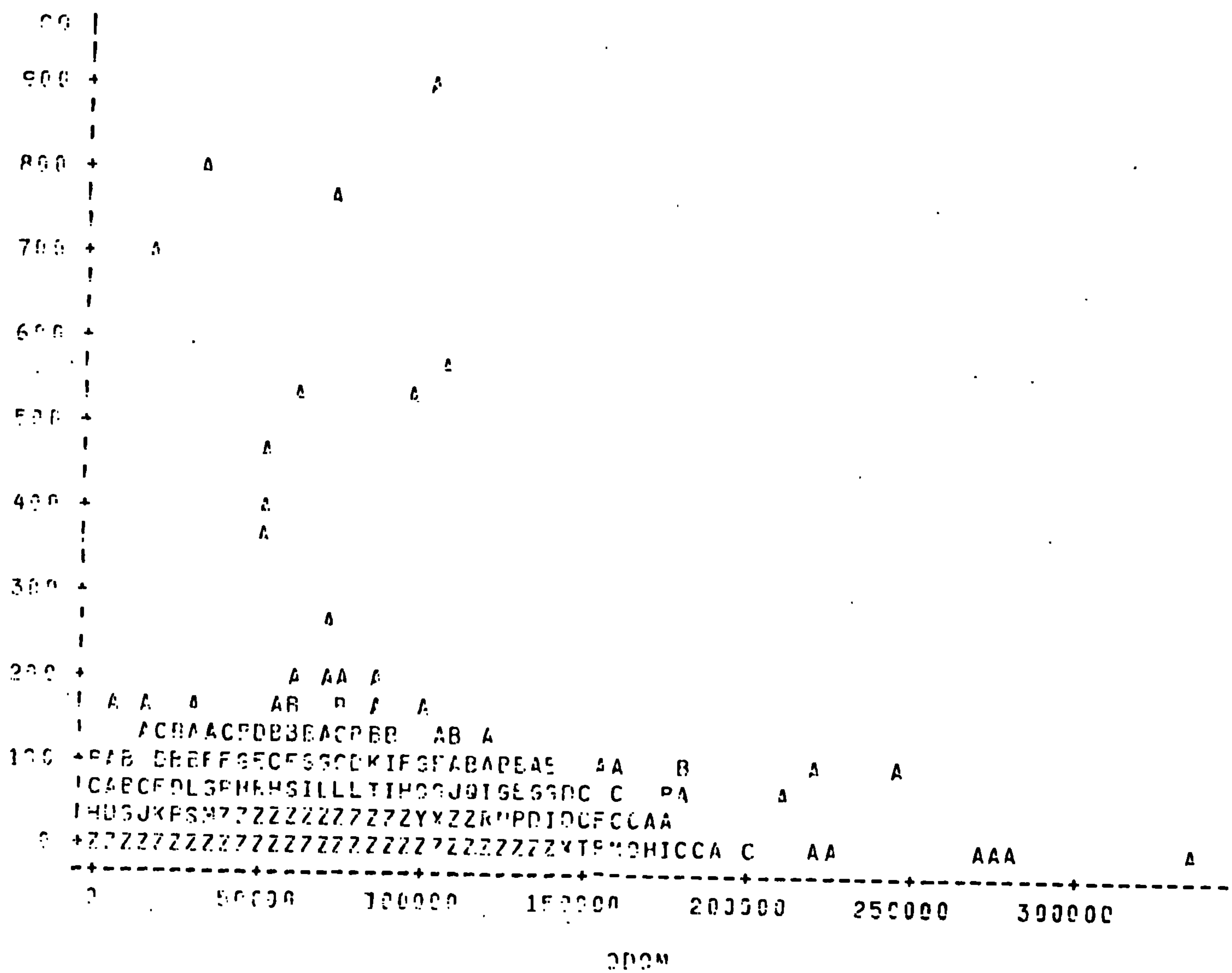
When the emissions are averaged for different groups of odometer readings, i.e. 0-10,000 miles, 10,000-20,000 miles, as shown on Figure 2-21, there does appear to be a trend towards increasing HC and CO emissions. The reason for this trend can be explained by looking at the emissions as a function of odometer reading separately for vehicles that pass and fail the I/M test. As shown on Figure 2-21, the average emissions from vehicles that pass the I/M test do increase with odometer but generally at a rate much lower than the rate for the total vehicle population. The average HC emissions varied from approximately 50 ppm at zero miles to approximately 80 ppm at 150,000 miles. On the other hand, the overall average emission concentrations varied from approximately 50 ppm to over 160 ppm at 150,000 miles. Figure 2-22 shows the average emissions of the vehicles that failed the I/M test, and although very high, they do not increase with odometer reading. Consequently, the increase in average emissions as a function of odometer reading for the overall vehicle population can be explained by the greater I/M failure rate for the high mileage vehicles. Furthermore, the data indicate that a properly adjusted or maintained vehicle can continue to emit low quantities of hydrocarbons or carbon monoxide when it has accumulated high mileage. These trends are consistent through each individual model year.

TAXI - SUMMARY STATS
MODELYR = 1981

5480 OBS HIDDEN

Figure 2-19. Plots of HC vs. Odometer

TAXI - SUMMARY STATS
MODELYR=1981



6974 OBS HIDDEN

Figure 2-20. Plots of CO vs. Odometer

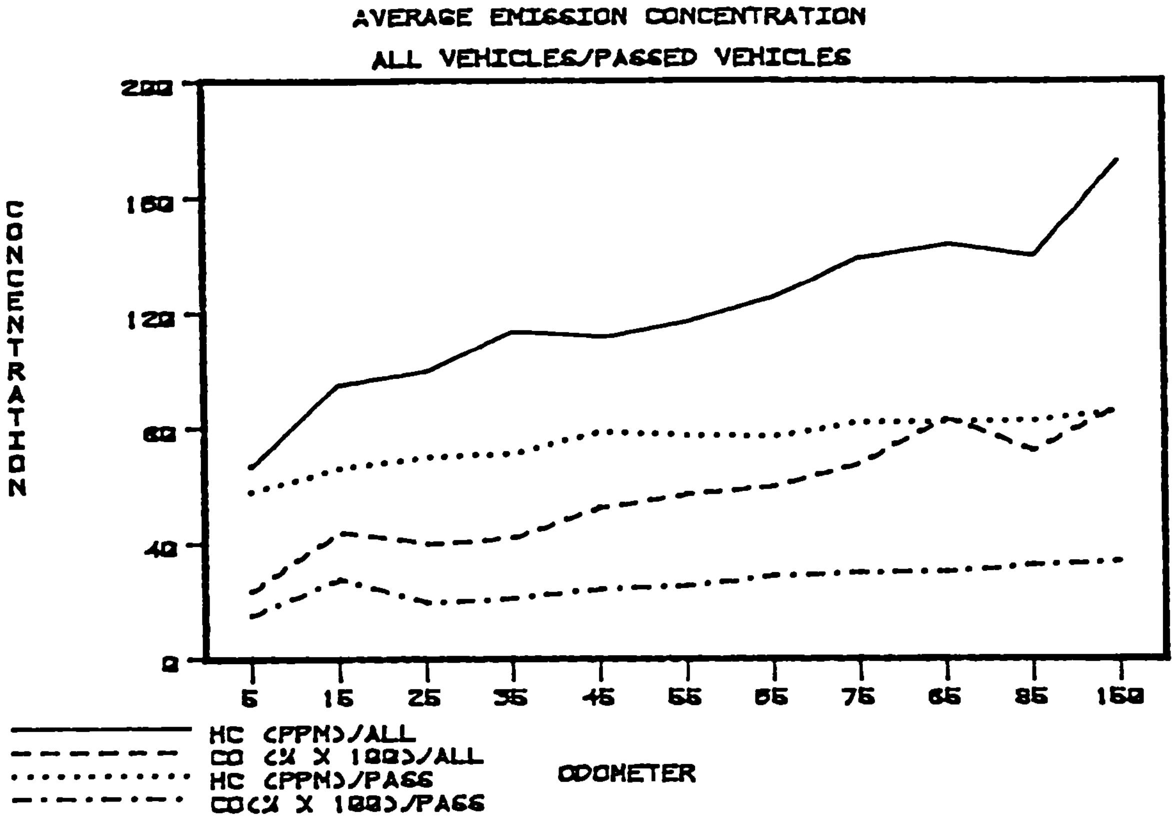


Figure 2-21. Average Emission Concentrations by Odometer

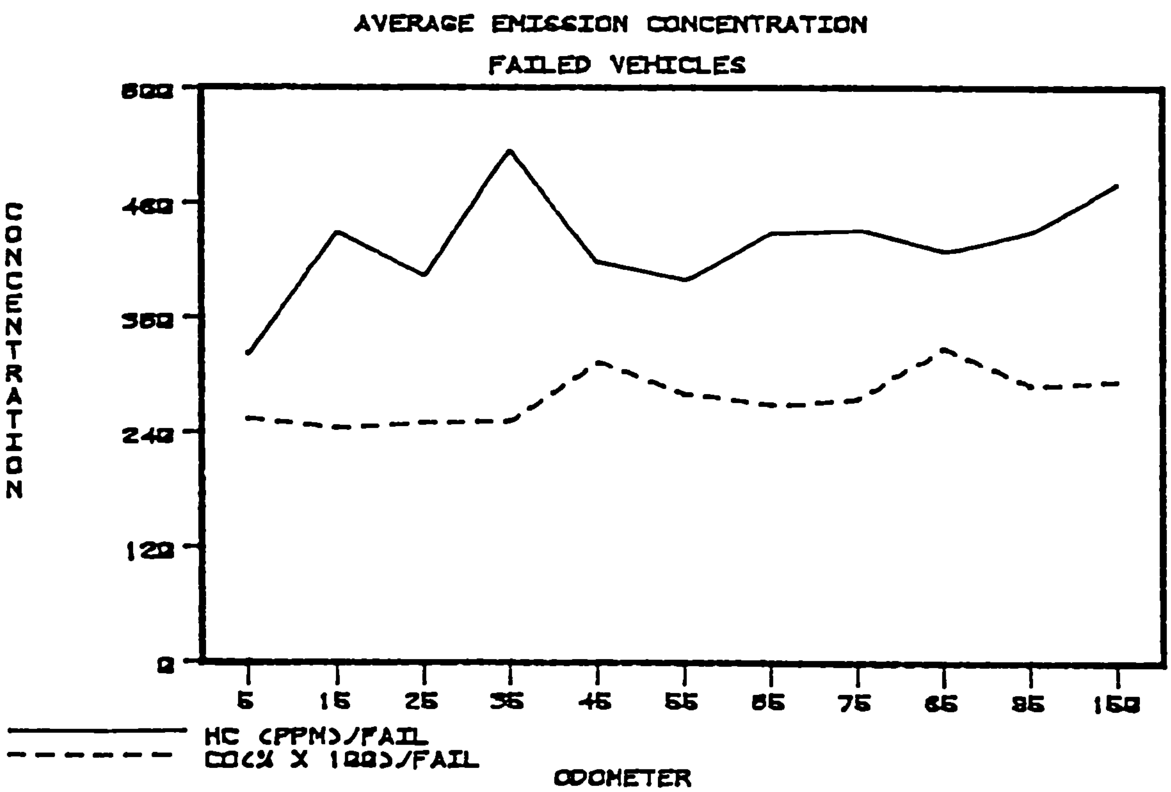


Figure 2-22. Average Emission Concentration by Odometer - Failed Vehicles Only

2.2.4 Emission Reductions

The data base contains the results of the retest performed on vehicles that failed the initial inspection along with the final inspection status, i.e. the results of the retest. Table 2-7 shows the emission reduction of the different groups of vehicles. As shown, the average percent reduction in HC emissions generally exceeded the average percent reduction in CO emissions. However, percent reduction in average emissions of the vehicles before and after repairs was greater for CO than HC. The standard deviation of the percent reduction in CO emissions explains this inconsistency. Standard deviations over 100 percent indicate that some vehicles showed increases in emissions over 100 percent. The maximum reduction theoretically is less than 100 percent. Since CO emissions can be extremely low, i.e. less than .1%, a small absolute increase could equate to a several hundred percent increase, thereby reducing the average percent reduction figure and increasing the standard deviation.

Table 2-8 and 2-9 illustrate that the average percent reduction is influenced by a small percentage of vehicles that show increases in emissions. Table 2-8 shows the CO emission reductions for vehicles passing and failing the retest; Table 2-9 shows the HC emission reductions. As shown when the repair targeted on the pollutant of concern, the effect of the repair on that pollutant was much more consistent, i.e. there was a much lower standard deviation. For example, for the cases where CO is reduced, the standard deviation is much lower than the overall group that passed on retest. Similarly, HC reductions are consistently greater and the standard deviation is consistently lower for the vehicles where HC is reduced. As shown on Table 2-8, for the group where CO increases, the CO emissions after repair are 0.61% which is significantly higher than the rest of the vehicles that passed on retest. For the case where HC increases, the increase is not excessive (29%), and the average HC emissions fro this group (130 ppm) is still much lower than the standard of 220 ppm. The increase in CO emissions from repairs appears to be a greater concern than the increase in HC emissions both because of the magnitude of the increase

TABLE 2-7 EMISSION REDUCTIONS FOR FAILED VEHICLES

		HC			CO		
		Avg. % Red.	Std. Dev. of % Red.	% Red. in Avg. Emis.	Avg. % Red.	Std. Dev. of % Red.	% Red. in Avg. Emis.
1980	All	67%	34%	78%	50%	114%	91%
	Chevy *	72%	27%	82%	27%	128%	86%
	Dodge	45%	49%	69%	56%	142%	91%
	Ford	66%	36%	78%	72%	89%	93%
1981	All	61%	30%	74%	44%	123%	88%
	Chevy *	66%	24%	78%	27%	132%	87%
	Dodge	52%	34%	68%	49%	117%	85%
	Ford	77%	18%	82%	85%	98%	97%
1982	All	68%	25%	77%	49%	139%	88%
	Chevy *	75%	22%	82%	44%	169%	91%
	Dodge	58%	28%	68%	69%	38%	81%
	Ford	--	--	--	--	--	--

* Including Checker

TABLE 2-8

CO EMISSION REDUCTIONS FOR VEHICLES PASSING AND FAILING RETEST

	% of Vehicles	Avg. CO before (%)	Avg. CO after (%)	% Reduction in Avg. CO	Avg. % Reduction CO	S.D. % Reduction in CO
Pass on Retest	98%	3.39	0.36	89%	46%	120%
• HC and CO are reduced	87%	3.67	0.34	91%	74%	33%
• CO is reduced/HC increases	2.7%	3.52	0.51	86%	75%	25%
• HC is reduced/CO increases	8%	0.24	0.61	(-154%)	(-259%)	252%
• HC and CO increases	0%	-	-	-	-	-
Fail on Retest	2%	4.45	2.30	48%	(-3.0%)	165%

Sample Size = 1621

S.D. - Standard Deviation

TABLE 2-9

HC EMISSION REDUCTIONS FOR VEHICLES PASSING AND FAILING RETEST

	% of Vehicles	Avg. HC before (ppm)	Avg. HC after (ppm)	% Reduction in Avg. Emis.	Avg. % HC Reduction	S.D. % HC Reduction
Pass on Retest	98%	427	101	76%	64%	32%
• HC and CO are reduced	87%	418	98	77%	66%	24%
• CO is reduced/HC increases	2.7%	101	130	(-29%)	(-48%)	62%
• HC is reduced/CO increases	8%	625	121	81%	71%	22%
• HC and CO increases	0%	-	-	-	-	-
Fail on Retest	2%	810	569	30%	26%	39%

Sample Size = 1621

S.D. - Standard Deviation

(154% in average CO emissions) and the percent of vehicles affected, 8% CO vs. 2.7% HC. Note on Table 2-8 and 2-9 that the after repair emission levels are only slightly higher than emission levels of vehicles that pass the I/M test (see Table 2-2).

Figure 2-23 shows the average percent reduction for the 1981 and 1982 model year vehicles as a function of odometer. As shown, the percent reduction appears to be insensitive to odometer, indicating that the emissions from high mileage vehicles can be reduced by the same percent as the emissions from low mileage vehicles. However, since the idle test does not measure catalyst activity to a great degree, it is difficult to extrapolate these results to FTP emissions; i.e. the percent reduction in FTP emissions may be lower at high mileages. Additional data would be useful to address this issue.

2.3 ANALYSIS OF DATA FROM ROADSIDE CHECKS

In addition to analyzing data collected during the I/M tests, Radian also analyzed data collected during roadside checks performed by DEP personnel. The roadside check data is useful for a number of reasons:

- The DEP personnel are likely to perform more accurate inspections than the inspections performed by inspectors certified by the Taxi and Limousine Commission.
- The vehicle owner/operator does not have an opportunity to prepare the vehicle for the test, consequently, the results are more representative of vehicles operating on the street.
- The roadside test data were collected much more recently and therefore are able to give an indication of the performance of 1983 model vehicles along with a more thorough indication of the high mileage performance of the 1982 model year vehicles.

The roadside data showed somewhat similar results to the I/M data. As shown in Table 2-10, the roadside failure rate was much higher than the

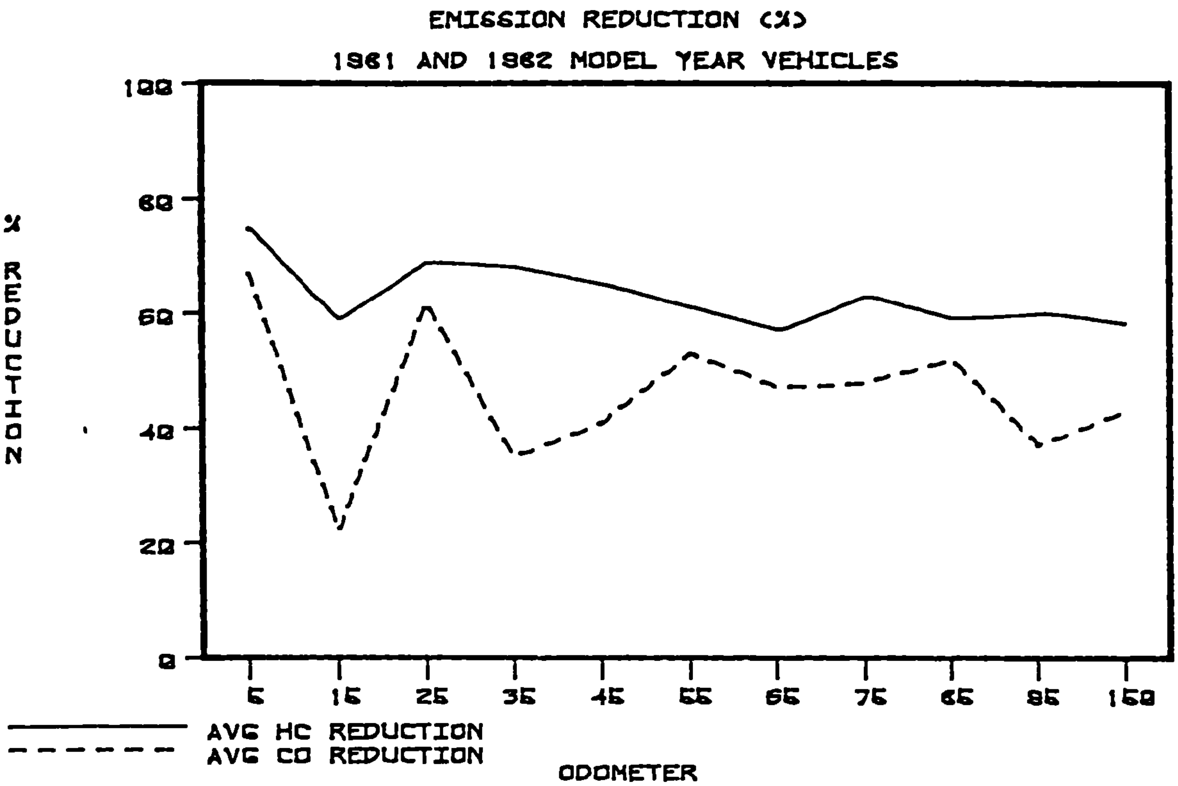


Figure 2-23. Average of Reduction as a Function of Odometer

TABLE 2-10 COMPARISON BETWEEN ROADSIDE CHECK DATA AND I/M DATA

		Roadside Checks Data					I/M Data				
Model		Avg. HC (ppm)		Avg. CO (%)			Avg. HC (ppm)		Avg. CO (%)		
Year	Make	Pass	Fail	Pass	Fail	% Failure	Pass	Fail	Pass	Fail	% Failure
1980	All	71	403	0.24	2.16	28%	77.3	497	0.31	2.44	14%
	Chevy	98	432	0.25	1.31	31%	86.7	574	0.29	1.09	13%
	Dodge	63	540	0.17	0.67	17%	63.6	331	0.34	4.04	14%
	Ford	68	343	0.27	3.56	31%	74.2	452	0.33	3.48	16%
1981	All	82	464	0.24	3.14	36%	79.4	441	0.27	3.11	16%
	Chevy	82	498	0.27	2.88	39%	82.1	509	0.27	2.77	13%
	Dodge	84	412	0.24	3.92	39%	78.7	383	0.26	3.16	27%
	Ford	88	395	0.21	3.30	25%	76.1	404	0.28	4.72	11%
1982	All	80	501	0.14	3.48	24%	60.6	409	0.14	2.30	4.5%
	Chevy	86	497	0.15	3.62	30%	61.5	470	0.13	2.25	4%
	Dodge	69	640	0.11	2.90	11%	67.1	275	0.18	1.90	7%
	Ford	64	240	0.11	0.10	4.1%	47.0	307	0.12	3.77	4%
1983	All	46	262	0.11	1.39	4%					
	Chevy	41	326	0.11	1.15	4%			NO DATA		
	Dodge	53	188	0.11	1.40	4%					
	Ford	--	---	----	----	--					

I/M failure rate; however, the trends from model year to model year were similar. For example, the failure rate for 1981 Chevy and Checker vehicles was higher than the 1980 failure rate. Considering that the roadside data were collected in the Summer of 1983 vs. 1982 for the I/M data, the higher failure rate for the 1981 models is consistent with the I/M data that shows a higher failure rate for the 81 Chevrolets when the failure rate is standardized by odometer. The roadside data also showed that the emissions reported in the I/M test appear to be reasonable after the obvious errors are removed. As shown on Table 2-10, there is little difference between the average emissions of the passed and failed vehicles in either the roadside test or the I/M test. The roadside test sometimes includes a tampering inspection but no 1980 and newer vehicles had obvious evidence of tampering.

Table 2-11 shows the emissions distributions in the roadside checks. Also like the I/M data, the roadside data show a greater percentage of vehicles with excessively high CO emissions in the 1981 model year. The roadside test data also indicate that the 1982 Chevrolets show similar performance to the 1981 model year vehicles; i.e. greater CO emissions than the 1980 model year vehicles. The problems mentioned in Section 2.4 with the oxygen sensors and the evaporative purge valves could be responsible for these trends. It is interesting to note that, unlike the failure rates, the percent of gross CO emitters in the roadside checks were not higher than in the I/M tests. Possibly, vehicle driveability problems cause the owner/operator to repair vehicles with extremely high CO emissions.

The comparison between the 1982 model year vehicles in the roadside checks and the I/M checks is not valid since the I/M data was based on much newer vehicles than the roadside data. A more valid comparison would be between the I/M data on the 1982 model year vehicles and the roadside test data on the 1983 model year vehicles. As shown, there is little difference between the failure rates and the emissions distributions of these two groups.

TABLE 2-11

EMISSION DISTRIBUTIONS IN ROADSIDE CHECKS

Model Yr.	Make	HC % > than 300 ppm	HC % > than 700 ppm	CO % > 3.0%	CO % > 7.0%	Count
1980	All	17	4	8	0%	195
	Chevy	20	3	4	0	101
	Dodge	6	6	0	0	18
	Ford	17	4	15	0	71
1981	All	19	6	13	3	240
	Chevy	26	7	14	3	137
	Dodge	16	5	18	5	38
	Ford	8	3	10	2	59
1982	All	13	5	11	3	173
	Chevy	18	6	14	5	125
	Dodge	4	4	4	0	26
	Ford	0	0	0	0	22
1983	All	1	0	0	0	200
	Chevy	1	1	0	0	104
	Dodge	0	0	0	0	82
	Ford	--	--	--	--	14

As noted, the roadside test failure rate for the 1981 Chevrolets was three times higher than I/M tests; however, the roadside failure rate for the 1981 Dodges and Fords was not elevated to the same degree. This could indicate that the owners are more aware of problems with the Chevrolets because of check engine lights and are likely to obtain repairs prior to the I/M test. However, the random nature of the roadside tests does not give the owner/operator opportunity to repair the vehicle even if he knows there is a problem, unless driveability is severely affected.

In summary, the roadside data confirmed that the 1981 and 1982 Chevrolet vehicles show inferior CO and possibly HC performance to the 1980 model year vehicles. The closed-loop fuel control system in the 1981 model year is likely to be responsible for this change. The roadside check data also confirmed that the 1981 Dodge 225-6 engine apparently has a carburetor problem as evidenced by its extremely high failure rate in the roadside check.

The high failure rates in the roadside checks are troublesome, considering that the taxis are inspected every four months. Are vehicles being incorrectly passed -- either initially or after repairs; are the in-use disablement rates so high that the failure rate is justifiable; are vehicles being re-adjusted after repair? Additional data would be useful in determining the cause of failure for vehicles inspected in the roadside checks.

2.4 RESULTS OF MEETINGS WITH MAINTENANCE PERSONNEL IN TAXI FLEETS

As part of the analysis of data from the New York Taxi I/M program, meetings were held with maintenance personnel in three of the major taxi fleets:

- Midland (operates 1982 Checkers equipped with 229 V6 Chevy engines)

- Metro (operates 1983 Chevys equipped with 229 V6 Chevy engines)
- 57th Street Metropolitan (operates 1983 Dodges equipped with 225 cubic inch 6-cylinder engines)

2.4.1 Fleets Operating Chevrolet/Checker Cabs (Midland and Metro Cab Co.)

Midland Cab Company. Midland Cab Co. has experienced frequent failures of the evaporative purge valve used in the 1982 Checkers with 229 V6 engines. This valve is located in the line between the canister and the carburetor and is used to purge the canister vapors into the carburetor. Apparently the valve is failing in the open position which causes the carburetor to run in the equivalent of a full rich mode, and in time the rich operation of the engine fouls the oxygen sensor. The problem is usually noticed by an operator complaining about poor gas mileage. Fuel economy is frequently charted and is typically in the area of ten miles per gallon in city traffic. When the carburetor fails in the rich position, operators have noticed that the fuel economy drops down to around 7 miles per gallon. Some operators have noticed that the check engine light has come on, although many times operators fail to mention the check engine light. (It does not always remain illuminated.) The maintenance supervisor said that 1981 Checkers with the same basic engine as the 1982 models did not experience frequent problems with the evaporative purge valve. The only major problem that they experienced on the 1981 model was water collecting around the oxygen sensor, causing it to short out.

Midland diagnoses its engines by reading the codes stored in the computer using the check engine light procedure that GM developed. The GM diagnostic system has been reliable and is the primary method used to identify possible sources of the problem. Usually the computer indicates a defective oxygen sensor. Further investigation has led to the identification of the evaporative purge valve as the main culprit.

The Checker cabs experience random failures of the carburetor and the computer. Midland also has replaced the oxygen sensor every 30,000 to 40,000 miles even if the evaporative purge valve is operating correctly. During the meeting, maintenance logs on four vehicles were reviewed and every log showed replacement of the oxygen sensor at approximately 30-40,000 mile intervals, and some showed more frequent intervals. Midland also has encountered fialures of the catalytic converter. In this case, the problem was either poor fuel economy or no power because of the collapsed converter. Up to 50,000 miles they have been obtaining new converters from GM; however, they also had to purchase many new converters because they accumulate mileage at a rate of approximately 50,000 per year.

Metro Cab Company. Metro operates a fleet of 1983 Chevys with the 229 cubic inch V6 engine. Like Midland Cab Co., Metro also has been experiencing frequent failures of the evaporative purge valve. Metro noted that failures have been experienced on the 1983 model. Similarly, the problem has been identified by the poor gas economy, poor engine operation or a check engine light. In order to diagnose the problem in their vehicles, Metro uses a Mini-Scanner to read the codes stored in the computer. Metro notes that most of the problems experienced with the 1983 Chevys are related to the computer system. They encounter few ignition related problems. Like Midland, Metro has to replace the oxygen sensor at periodic intervals and the average carburetor lasts 40-50,000 miles before needing replacement or an overhaul. In the new fleet of Chevys (1983 models) approximately 150 our of 200 have had oxygen sensors replaced. Metro has also had to replace some catalysts. In some cases they experienced catalyst melting and at other times the catalyst breaks off and plugs the exhaust. Metro has worked closely with the AC division of GM in diagnosing the problems with their vehicles.

Metro Cab Co.'s maintenance program operates independently of the I/M program. Although the I/M program identifies high emitting vehicles, Metro felt that these vehicles would be identified in the normal course of action because of driveability or fuel economy problems or illuminated check engine lights.

2.4.2 Fleets Operating Dodge Cabs (57th Street Metropolitan Cab Company)

The 57th Street Cab Company operates a fleet of 1983 Dodges equipped with the 225 cubic inch 6 cylinder engine. Previously, they operated a fleet of 1981 Dodges. Unlike the other two fleets, there have been no major mechanical problems such as the evaporative purge valve in the 1981 or 1983 Dodges. Most of the vehicles that failed the I/M test are repaired by a carburetor adjustment. Although the 1983 225 engine is closed-loop, the idle circuit is open-loop. Consequently, idle mixture adjustments are performed in a more traditional manner than adjustments on GM vehicles. No special equipment is needed to diagnose the problems in the Dodges.

The maintenance supervisor for 57th Street noted that occasionally carburetors are fouled with carbon. The carbon canister has been identified as being the source of the carbon. To eliminate the problem, an in-line filter was placed in the purge line that runs to the carburetor. Sometimes broken off oxygen snesors have been found along with vacuum leaks and defective vacuum amplifiers. The 57th Street Cab Company services its vehicles every 21 days which is the equivalent of every 7,000 miles. This service includes a complete tuneup, brake shoes, and an exhaust emission test. The service is done in addition to the I/M program.

2.4.3 Summary of Meetings

All three taxi fleets appeared to provide unbiased answers to questions raised. The problem the 229 V6 Chevrolet engine has with full rich failures from defective purge valves appears significant and should be investigated further. This problem could explain the high failure rate for 1982 Chevrolets in the roadside checks. A much more in-depth analysis is needed to accurately determine the cause of failure or to determine the seriousness of the evaporative purge valve problem. Additional information is needed to determine if the problem is confined to the 229 engine families.

3.0 CONCLUSIONS/RECOMMENDATIONS

3.1 CONCLUSIONS

Several conclusions concerning the high mileage emission control performance of new technology vehicles can be drawn from this analysis:

- 1981 and possibly 1982 vehicles with the 229 cubic inch Chevrolet engines appear to have greater CO and to a lesser extent greater HC emissions than 1980 model year vehicles. The closed loop fuel metering system may be responsible for this trend.

- 1981 Dodge vehicles with the 225 cubic inch engines also appear to have greater CO and HC emissions than comparable 1980 models.

- 1981 Ford vehicles have very similar HC and CO emissions to the 1980 models which is expected because of similar fuel metering system designs.

- The failure rate in the I/M test is strongly dependent on odometer reading.

- The HC and CO emission levels of vehicles that pass the I/M test are not strongly affected by odometer.

- After repair emission levels of failed vehicles are similar to the emission levels of vehicles that pass the I/M test.

- Although a vehicle could have failed up to four times, most vehicles that failed only failed once. 1981 Dodge models show the greatest tendency towards repeat failures.

- A majority of vehicles emitting moderately high amounts of CO also emit moderately high amounts of HC; however, a majority of the moderately high HC emitters do not emit moderately high amounts of CO. Considering that excess HC emissions are caused by factors in addition to fuel enrichment, this finding is logical.

- The failure rates in the roadside checks are much greater than the failure rate in the I/M test. However, the roadside checks do not show significantly greater percentages of gross emitting vehicles (greater than 7.0% or 700 ppm HC).

The greater failure rates in roadside checks could be
be the results of:

--improper passing of vehicles in the I/M test
--inadequate repairs
--readjustments after repairs
--excessive disablement/deterioration rates
--greater odometer readings on vehicles tested in roadside checks.

- For Chevrolet and Ford vehicles, the percentage of gross CO emitters (greater than 7.0%) does not appear to increase with odometer after approximately 50,000 miles are accumulated.

- 1982 Chevrolets with the 229 cubic inch engine have had frequent failures of the evaporative purge valves which have resulted in excessive HC and CO emissions and fuel consumption. Oxygen sensors, ECMs and carburetors also have been replaced more frequently than manufacturer's expected intervals.

3.2 RECOMMENDATIONS

Based upon this analysis, the following recommendations are made for additional analysis:

- Perform additional surveys of maintenance personnel to better determine:

  --the type of repairs required to bring new technology vehicles into compliance, and
  --frequency of defects/disablements in new technology vehicles.

- Collect additional data during roadside checks on:

  --odometer
  --check engine light status
  --trouble codes (use a Mini-Scanner to read the codes)
  --plumbtesmo/other tampering
  --other diagnostic checks.

- Analyze I/M data collected beyond May 1983 to determine trends for 1982 and 1983 vehicles.

- Perform FTP's on taxis at DEP's Frost St. Lab.

- Investigate other GM engine families/evap families to determine the extent of the evaporative purge valve problem.